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(54) **STATOR MANUFACTURING METHOD AND WHIRLING CUTTER DEVICE**

VERFAHREN ZUR HERSTELLUNG EINES STATORS UND WIRBELSCHNEIDEVORRICHTUNG

PROCÉDÉ DE FABRICATION DE STATOR ET DISPOSITIF À LAME TOURNOYANTE

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Description

[0001] This invention relates to methods of machining the stators of progressive cavity pumps and to a whirling cutter device that may be used in the methods. However, the stator of such pumps corresponds with the stators of progressive cavity motors and therefore the invention is also applicable to such stators. The present invention finds particular application in the small size range.

BACKGROUND

[0002] Stators of such machines are frequently moulded from rubber or like elastomer, where a core of the mould is unscrewed from the stator bore after moulding. This is perfectly satisfactory in many respects, except there is a demand for greater performance. Indeed, the lobes of such machines absorb considerable stresses and can fracture across their root. Stators constructed from a more solid material such as steel or some composite that is not easily moulded, are feasible. Such stators may have a constant thickness rubber or elastomeric coating to provide the cushioning that is generally desirable for progressive cavity machines. Providing the bore of such stators is problematic, however.

[0003] As the skilled person will know, progressive cavity machines have an x-lobe stator and an (x-1)-lobe rotor (where x is an integer of positive value) that both orbits and rotates inside the stator. The lobes of both the stator and rotor twist along their length so that in any given rotational position of the rotor with respect to the stator there is a twisted cavity that tapers to a close at each end thereof and progresses up, or down, the stator and rotor on rotation of the rotor in the stator. Forming the bore of the stator is straightforward in some materials and at some sizes. But where it is to be cut in a hard material, and it is of a small diameter, then it poses particular problems.

[0004] Our co-pending international patent applications publication numbers WO2008/129237 and WO2010/049724 both describe a machining apparatus and process that is effective for large diameter stators. However, two-lobe stators, and stators of small diameter, present special problems that the apparatus disclosed in the aforementioned applications, or one working on similar principles, cannot accommodate. With a two-lobe stator, being machined using a right-angled milling tool on a body that is a sliding fit inside the bore of the tube being machined, (the bore being substantially equal to the minor diameter of the stator to be formed), the tool that finally finishes the lobe on each side of the stator must comprise a ball nose cutter whose diameter is equal to the minor diameter of the stator. This imposes a significant load on the tool and its support within the bore, such that it cannot reasonably be accomplished in material that has any substance (by that, is meant significant resistance to cutting).

[0005] WO2008/129237 A1 describes apparatus that is suitable for machining the lobes of a multi-lobe progressive cavity stator (ie one having more than two lobes). The apparatus comprises an elongate arm on which is disposed at a transverse angle a machining head to mill the cylindrical bore of a tube, the bore diameter at the commencement of milling being formed at the diameter of the minor diameter of the bore ultimately to be formed. The machining head is arranged to have steadies that support the machine head, the steadies engaging with the minor diameter that reduces as machining progresses to a helical land on the minor diameter.

[0006] In the process described in WO2008/129237 A1, which represents the closest prior art for independent claim 1, the lobes are progressively machined using first a shallow cutter to produce a broad trough. As the cutter progresses into the workpiece, the workpiece is twisted so that the trough forms a helix. Then, succeedingly narrower and deeper cutters are used until a stepped profile approximating the sinusoid shape of the desired end profile is obtained. Finally, a shaped cutter having the desired profile of the trough is used. The same process is employed for each lobe.

[0007] With anything more than two lobes, there is plenty of support for the machine head, and sufficient cross section of the minor diameter to supply easily the power required to machine the lobes between the minor and major diameters. Those lobes do not, in any event, represent a significant proportion of the area enclosed by the major diameter; and nor does the difference between the major and minor diameter represent a significant proportion of the minor diameter. Accordingly, the system works well with larger diameter tools having multiple lobes. For example, consider a theoretical three lobe stator that has a bore for supporting the tool on in a circle that is the minor diameter. The lobes to be machined can be thought of in terms of an equilateral triangle whose sides are tangents to the minor diameter circle. Thus the lobes to be cut are the triangular tips of that triangle and it can be seen that the maximum diameter of the tips is at 0.86R, where R is the radius of the minor diameter. This is still a substantial proportion of the minor diameter circle but it should also be appreciated that the amount of material to be removed at this diameter is merely the side tips of said triangular tips and amount to very little material at this diameter. Consequently, the tool of our aforementioned specifications is adequate. Contrast this with the elongate rectangular (albeit with round ends) profile of a two-lobe stator, and where there is substantial material to be removed at the full width of the minor diameter.

[0008] Thus, when the diameter of the machine is reduced and the number of lobes correspondingly reduced to two, this method and tool does not perform satisfactorily. The proportion of material to be removed versus the area of the bore available to transmit power increases. Moreover, the proportional distance that the cantilever between the tool edge and its support also increases (as represented by the eccentricity of the stator bore -

being the ratio of major to minor diameters). But more importantly, as described above, it is the diameter of the cutter required compared with the diameter of bore available to accommodate the tool body that defeats this method. Consequently it is an object of the present invention to develop an improved process for machining helical profiles in stator bodies of relatively small diameter. By small is meant with just two lobes and a minor diameter less than about 60 mm. However, whilst the invention is restricted to two-lobe stators, it is not actually limited to any particular diameter and could be employed in larger diameter stator bodies.

[0009] GB-A-1265743 discloses a multi-purpose milling head having a longitudinal axis and providing a rotary cutter rotatable about an axis parallel the longitudinal axis and offset by variable amounts, useful for cutting external threads on large diameters.

[0010] US 4,813,828 discloses a whirling cutter device having the features of the preamble of claim 6 in combination.

[0011] CN 101 147 989 A, which represents the closest prior art for the method of independent claim 14, discloses a method of machining the bore of a lobed stator comprising the steps of providing the stator with a bore having a minor diameter, providing a whirling cutter device, which device comprises a cutter head on the end of a shaft having a longitudinal axis and a diameter thereabout, the cutter head having a journal member for mounting a whirling cutter for rotation of the cutter about an axis parallel to said longitudinal axis but offset therefrom, passing the device through the bore so that the whirling cutter cuts the bore and simultaneously rotating the stator with respect to the device so that the bore cut is helical.

BRIEF SUMMARY OF THE DISCLOSURE

[0012] In accordance with the present invention, there is provided a method of machining the bore of a two-lobe stator for a progressive cavity machine according to claim 1. The bore has a desired profile along a longitudinal axis of the bore comprising a minor and a major diameter and an helically varying radial axis along said longitudinal axis and defining a helix pitch, said profile being defined, at any axial position along said longitudinal axis, by the area swept by a circle of diameter equal to said minor diameter being translated along said radial axis by an equal displacement amount on either side of said longitudinal axis. The method comprises the steps of:

a) providing a tubular stator body with a cylindrical bore centred on said longitudinal axis and of diameter not less than said minor diameter, and first and second machining devices that are each a close sliding fit on said minor diameter, wherein

b) the first device comprises a milling head on the end of a shaft, the milling head mounting a rotary cutter arranged for rotation about an axis transverse said longitudinal axis by a drive mechanism along the shaft;

c) the second device comprises a cutting head on the end of a shaft, the cutting head mounting a whirling cutter for rotation about an axis substantially parallel to said longitudinal axis but offset therefrom by a selectively variable degree between a minimal and maximal separation of the whirling cutter axis from the longitudinal axis;

d) driving the first device through the bore so that said rotary cutter follows a helical path with said helix pitch, in the process milling a groove along said path in the stator bore using a sufficiently small diameter rotary cutter that the torque necessary to drive the cutter remains within the capacity of the drive mechanism;

e) angularly offsetting the rotation axis of the rotary cutter of the first device with respect to the radial axis and again driving the first device through the bore along said helical path, milling a further helical groove in the stator bore, also using a sufficiently small diameter rotary cutter that the torque necessary to drive the cutter remains within the capacity of the drive mechanism;

f) extending the depth of cut of the rotary cutter of the first device and repeating steps d) and e) without over cutting the desired profile;

g) driving said second device through the bore so that the whirling cutter follows said helical path with the rotation axis of said whirling cutter intersecting said radial axis and cutting elements of the whirling cutter milling the stator bore to a diameter equal said minor diameter, wherein said cutting head is translated along said radial axis by said displacement amount along said longitudinal axis.

[0013] What this last step g) means is that, at the least, the whirling cutting head is set at said displacement amount and translated along said helical path (along said longitudinal axis) so as to mill out the stator bore at each major diameter of the bore (bearing in mind it is a double helix on either side of the longitudinal axis), as well as being set at intermediate positions to mill out the stator bore at positions between the two extremes. While the "ends" of the bore in any section will be circular (or, rather, semi-circular) being as required, the lines joining the ends of the ends should be straight. Using a circular cutter tangentially to such lines inevitably will leave ridges, unless the cutter is also moved along the line. However, if this is done, there is the possibility of ridges being formed in the longitudinal direction.

[0014] Preferably, said method further includes the step of:

h) said cutting head being set at a radial displacement and driven along said helical path before being indexed to a different radial displacement and again driven along said helical path, said process being repeated until said translation is approximately com-

plete.

[0015] Alternatively, said method further includes the step of:

i) said cutting head being arranged to be driven along said radial axis by a radial drive while said second device is within the stator bore.

[0016] In that event, preferably,

j) said drive is operated to drive said cutting head by said displacement amount along said radial axis before indexing said second device along the helical path and repeating the process until said translation is approximately complete.

[0017] Further alternatively, a combination of steps h) and j) is employed in that

k) said cutting head is continuously driven by said displacement amount along said radial axis while said second device is continuously driven along said helical path, and repeating the process until said translation is approximately complete

[0018] Said helical paths may be different from one another in the sense of being angularly offset and of different radii, but they are all parallel in the sense of having the same helix pitch.

[0019] Preferably, said whirling cutter has cutting elements that have V-shaped cutting faces whose points are on a circle of diameter equal to said minor diameter.

[0020] Preferably, said cylindrical bore of the stator body prior to machining is slightly greater than minor diameter to define a helical land that persists throughout the method and is employed to guide said first and second devices. Preferably, said first and second devices are each provided with steadies to bear against said helical land and support said heads.

[0021] In accordance with a further aspect of the present invention, there is provided a whirling cutter device according to claim 6. Such a whirling cutter device comprises a cutting head on the end of a shaft having a longitudinal axis and a diameter thereabout, the cutting head having a journal member on which is mounted a whirling cutter for rotation of the cutter about an axis parallel to said longitudinal axis but offset therefrom by a selectively variable degree between a minimal and maximal separation of the whirling cutter axis from said longitudinal axis, wherein the shaft has a support surface on said diameter suitable to bear against a material being cut by the whirling cutter device and wherein a helical profile in said material is capable of being cut by the whirling cutter device, said profile having a minor diameter, the support surface being suitable for bearing on the minor diameter to support said whirling cutter, wherein the diameter of the cutting path of the cutter when rotating about its axis is equal to the diameter of the shaft.

[0022] Preferably, said cutter head is mounted on an end face of said shaft, said face being perpendicular said longitudinal axis.

[0023] Preferably, said end face has a groove and said cutter head has a flange for reception in said groove, means enabling fixing of said head in said groove in different positions thereof along the groove. Furthermore said groove and flange are dove-tailed.

[0024] According to a preferred embodiment of the present invention, said journal member is driven by a drive member mounted for rotation in said shaft, a pair of universal joints separated by a displacement member enabling offsetting of the axis of rotation of the whirling cutter. Preferably said drive between the drive member and the journal member is via an intermediate member disposed in the cutter head, and said drive intermediate member is a gear meshing with a gear on said journal member. Preferably, said drive intermediate member is a pulley driving a belt wound around a pulley on said journal member.

[0025] In an alternative embodiment, said journal member is driven by a motor mounted on the end of the shaft, and preferably the motor is a hydraulic motor comprising first and second meshing gears located in a cavity supplied with hydraulic fluid, one of said gears being said journal member.

[0026] In accordance with all embodiments of the present invention, the whirling cutter is preferably mounted in a recess of an overarm attachment, attached to said end face of said shaft, wherein said recess has a first side and a second side perpendicular to said axis of rotation of said cutter. Said attachment is one of several attachments providing different one of said offset position.

[0027] In accordance with a further aspect of the present invention, there is provided a method of machining the bore of a lobed stator according to claim 14. The method comprises the steps of:

a) providing the stator with a bore having a minor diameter;

b) providing a whirling cutter device, which device comprises a cutting head on the end of a shaft having a longitudinal axis and a diameter thereabout, the cutting head having a journal member for mounting a whirling cutter for rotation of the cutter about an axis parallel to said longitudinal axis but offset therefrom by a selectively variable degree between a minimal and maximal separation of the whirling cutter axis from said longitudinal axis, and wherein the shaft has a support surface on said diameter;

c) passing the device through the bore so that the whirling cutter cuts the bore and simultaneously rotating the stator with respect to the device so that the bore cut is helical; and

d) supporting the shaft on the minor diameter of the bore during step c).

[0028] Preferably the method is repeated at a different rotational start position of the whirling cutter device with respect to the stator, whereby a plurality of lobes is cut.

[0029] In a preferred embodiment, the method is repeated at different offsets of the whirling cutter.

[0030] In accordance with a method as described above, a whirling cutter device according to one of claims 6 to 13 is preferably employed.

[0031] Offsetting the drive member in the way described above reduces the requisite angle of deflection of the universal joints and/or the length of the displacement member. Reducing the angle increases the power that can be developed. Reducing the length reduces the threshold speed above which eccentric whirling of the displacement shaft cannot be avoided.

[0032] Thus, the invention provides a means of machining the bore of a progressive cavity machine stator that does not overstretch the capacity of the machining equipment, and yet enables an accurate bore to be produced. The invention is predicated on the appreciation that the section of a two-lobe stator is as defined above, namely the area swept by a circle of diameter equal to the minor diameter translated along the radius of the longitudinal axis by a displacement amount that is equal, in practice, to the diameter of the eccentric orbit of the single helix rotor in the stator during use. Given this profile at any longitudinal position, a rotary cutter of diameter equal to the minor diameter and in the plane perpendicular to the longitudinal axis of the machine will machine the wall of the bore to precisely the correct shape if translated in said plane back and forth along said radius, across the centre

[0033] In the alternative mentioned above where the second device is driven through the stator body and the whirling head is then indexed to a different radial position, the precision of the final profile depends on the size of the index step. The final step takes the cutter to the position in which it cuts an entire one-half of a circle at the maximum offset. However, between the middle of the stator body (where it cuts nothing given that the starting bore is not less than the desired minor diameter of finished stator bore) and the maximum offset, there will be shallow ridges between each index step. However, as an example, for a stator of 27 mm minor diameter and 45 mm major diameter with six steps of approximately 3 mm results in a ridge between each step of about 0.05 mm height, which is perfectly adequate precision for most purposes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] Embodiments of the invention are further described hereinafter with reference to the accompanying drawings, in which:

Figures 1 a and b are a side section and a cross section of a two lobe stator to which the present invention relates, Figure 1 a being a section on the line A-A in Figure 1 b;

Figure 2 is a section showing the profile of the stator at any given point along its length;

Figure 3 is a perspective side section of the stator after formation using the method of the present invention;

Figure 4 is a section similar to Figure 2, but showing the first stage machining paths;

Figure 5 is a section similar to Figure 2 showing the profile after the first stage of machining is completed;

Figures 6a to d are perspective views of: the whole tool; the whole tool in side section; a transparent view; and a detailed view of the end of a tool for performing first stage machining operations;

Figures 7a to d are respectively: a perspective view of the whole tool; a perspective view of the end of the tool; a perspective view of the end in section; and a perspective view of a section of the end in a different position to that shown in Figure 7c; all of a second tool according to an aspect of the present invention and for performing second stage machining operations;

Figure 8a and b are sections, a) as per Figure 5, but showing the machining operations using the tool of Figure 7, and b) the resulting side of the profile (in enlarged detail);

Figure 9 is a side section of the tool of Figure 7 in use;

Figure 10 is a side section according to a different embodiment of the second tool, in which the whirling cutter is configured to make deep cuts;

Figure 11 is a side section of the apparatus in Figure 10 when configured to make shallow cuts.

Figure 12 is a side section according to an embodiment of the second tool showing the cutter head, in which a belt drive is employed;

Figures 13a and b are respectively a side section according to an embodiment of the second tool showing the cutter head arranged as a hydraulic motor, and a cross section;

Figure 14 is a side section according to an embodiment of the second tool, in which driving means is located inside the shaft of the tool;

Figure 15 is a side section according to an embodiment showing an overarm attachment;

Figure 16 is a perspective view of the overarm attachment of Figure 15; and

Figure 17 is a side section showing an alternative arrangement of the overarm attachment.

DETAILED DESCRIPTION

[0035] In the drawings, a stator 10 comprises a body 12 in the form of a tube having a bore 14. The bore 14 is a double helix whose profile at any position along a longitudinal axis 20, which is central to the bore 14 is an oval shape that is swept by a circle of diameter R_0 and radius R_1 translating from centre C_0 coincident with the longitudinal axis 20 to two further centres C_1, C_2. The

distance from C_1, or C_2, to C_0, is the eccentricity of the stator. Thus, starting with a tube having a central circular bore 16 of diameter R_0, at any axial position along the axis 20, C shaped segments 22,24 (hatched areas in Figure 2) must be removed. However, the radial axis 30 of the profile 14 rotates as the profile progresses along the stator 10 so that, when viewed from one end as shown in Figure 1b, there is only a circular bore visible, equal to the original bore 16 of the body 12. However, as mentioned above, the profile 14 is not circular but a double helix of pitch P, as shown in Figure 1 a. The diameter R_0 is referred to as the minor diameter, whereas the full width of the profile 14, which is equal to the sum of the minor diameter R_0 plus the separation of the centre's C_1, C_2, and this is referred to as the major diameter R_2. The profile of the ends 14a,14b (see Figure 2) of the bore section 14 is semicircular, with the sides 14c,d being parallel straight lines that are tangential to the ends 14a,14b.

[0036] For reasons explained further below, the starting bore 16 of the stator body 12 is actually slightly larger than the minor diameter R_0 Accordingly, when the machining operation to be described below is complete, a land 16a results, as shown schematically in Figure 3. The land 16a (which is flat in the longitudinal direction but circular in the circumferential direction with respect to the longitudinal axis 20) provides a bearing surface for the tools used to form the bore 14. The lands 16a both guide the tools and provide reaction surfaces for the forces exerted during machining.

[0037] Turning to Figures 6a to d, an example of a tool, schematically illustrated, suitable for performing the first stage of machining is illustrated. It is to be understood that the machine employed is of the type described in WO2008/129237 referred to above. By "type" is meant simply a tool with an angled - preferably right-angled - milling head). With specific reference to Figures 6a to d, the tool here exemplified comprises a cylindrical body 40 which formed in two halves 40a,b. The halves 40a,b are clam shells, and enclose an endless belt 42 that, at one end, is wound around a drive pulley 44 and, at the other, working end, is wound around a pulley 46 that is disposed in bearings 48 in a head 50 of the tool 100a.

[0038] Mounted in a bore 52 of the pulley 46 is a tool holder (not shown) in which a variety of milling tools (also not shown) can be fixed. By rotating the drive pulley 44, the tools rotate about an axis 120 which is perpendicular to the longitudinal axis 20a of the tool 100a. In use, the tool 100a is inserted into the cylindrical bore 16 of the stator body 10 until the head 50 extends beyond the end of the stator body 12. A tool is then fixed in the bore 52 (or in the holder if the holder does not extend beyond the diameter of the bore 16). The tool body 40 is a close sliding fit in the bore 16. The stator 10 is firmly held in a jig (not shown) and, while various options are possible, the preferred arrangement is that the tool 100a is driven so that the milling tool in the head is rotated and the tool 100a is slowly withdrawn back through the stator body 12 along the longitudinal axis 20 milling a groove on the bore 16. At the same time, the jig holding the stator body 12 arranges for the body 12 to rotate gradually about its longitudinal axis 20 so that it makes one complete revolution in the distance that the tool 100a moves the distance P. Thus the groove machined is helical, employing a combination of chuck rotation and linear movement of the tool.

[0039] Turning to Figure 4, the first pass of the tool 100a results in a channel 30a being removed. For this, a tool bit is employed having the dimensions of the groove 30a and in which the axis 120 of the tool 100a is aligned with the axis 30 of the major diameter of the bore 14 to be formed. When completed, the tool bit is removed and the tool 100a reinserted into the stator body 12. Then, the tool 100a (or, more likely, the stator body 12) is indexed through an angle A so as to offset the axis 120A. The same tool bit is then employed to machine a further groove 30b, overlapping the groove 30a, and removing more of the segment 22 to be machined away. This process is repeated with two further indexing steps and machining passes removing areas 30c and 30d respectively. When completed, and the tool 100a reinserted again into the bore 16 a new tool bit (not shown) is attached that has a longer reach and is arranged to remove further material 30e. Two further passes remove areas 30f and 30g.

[0040] The tool is then further extended to remove areas 30h and 30i before a final, longest reach tool, removes a shallow rectangular section area 30j. (In fact, in practice, the procedure will most likely also involves machining the right-hand quadrant of the area 22, as well as the opposite segment 24. This avoids having to change the bit too often.)

[0041] Next, three angled cutters are applied on the offsets at angles A, B and C (along axes 120A,B,C) the angled cutters having flanks 35, 33 and 31 respectively to remove triangular regions 30m, 30l and 30k respectively. Thus, a total of 22 passes are made removing the majority of the area 22 and leaving the profile 16b shown in Figure 5. Given that the amount of material used with each pass is very small, the tool 100a is quite sufficient in its structural capacity to effect the cutting operations in question.

[0042] However, the bore 16b is certainly not ready for use. Accordingly, the invention proposes to employ a second tool of which the tool 100b shown in Figures 7a to d is an example. Whereas the tool 100a might be regarded as a traditional milling tool, having a rotary cutter on an axis 120 transverse to the longitudinal axis of the tool, the tool 100b is best described as a "whirling tool" having a rotary cutting tool 80, also referred to as a whirling cutter, at one end 72 of a body or shaft 71 of the tool. The cutter 80 is mounted on a journal member 84 rotationally mounted within a cutter head 74 that is a sliding fit in a dovetail slot 76 formed in an end face 78 of the tool 100b. The cutter head 74 is correspondingly dovetailed at 79 to be a sliding fit in the slot 76. However, means (not shown) are provided to lock the cutter head

74 in any selected position within the slot 76. For example, a screw might be received in the cutter head 74 that impinges on the end face 78 pulling the cutter head 74 away from the slot 76 and tightly wedging the dovetail flange 79 with the slot 76. Other means of locking the cutter head 74 to the end 72 may be provided.

[0043] The cutting tool 80 that has a plurality of cutting bits 82, which preferably are V-shaped in profile and set on a circle of diameter equal to the minor diameter R_0 and in a plane orthogonal to the longitudinal axis 20b of the tool 100b.

[0044] With reference to Figure 7c, the cutting tool 80 is mounted on the end of the journal member 84 received in bearings 86 in the cutter head 74. The journal member 84 is driven by an intermediate (displacement) shaft 88 which is itself driven by a drive member 90 that extends through a bore 92 through the body/shaft 71. The drive member 90 is mounted in bearings 94 at each end of the bore 92. Between the intermediate shaft 88 and the journal member 84 and drive member 90 are a pair of universal joints 96 that enable drive from the shaft 90 to be maintained to the cutting tool 80 regardless of the lateral offset position of the cutter head 74 within the slot 76. Preferably, the intermediate shaft 88 is adjustable in length and may comprise, for instance, telescoping splined elements (not shown in detail).

[0045] Referring to Figure 7b, the slot 76 has an axis 122 that is transverse to the longitudinal axis 20b of the tool 100b and is, in fact, perpendicular thereto. Axis 124 of the journal member 84 is likewise perpendicular to the axis 122. Axis 122 is the direction of movement of the cutter head 74 in the slot 76. Axis 124 is, therefore, and remains, parallel to the longitudinal axis 20b of the tool 100b.

[0046] Turning to Figure 8a, the passes made of the tool 100b through the bore 16b (of Figure 5) are shown. First of all, the cutter head 74 is aligned with the body 71 of the tool 100b and the tool is passed through the stator 12, the body 71 again being a close sliding fit on the lands 16a. When the cutter head 74 extends through the open end of the stator body 12, the locking means (not shown) are released and the cutter head 74 displaced transversely along the axis 122 to a maximum displacement from the longitudinal axis 20b, which is here coincident with the axis 20 of the stator 12. The displacement is in the amount of half the distance between the centers C_1, C_2 described above with reference to Figure 2. When drive shaft 90 is operated to spin the cutting tool 80, the circular profile 16c of the end 14c of the major diameter of the bore 14 is formed. Again, the tool 100b is withdrawn through the bore of the stator 12, the stator being simultaneously rotated at the appropriate rate.

[0047] Indeed, with both the milling tool 100a and the whirling tool 100b, the cutting heads all describe a helical path in their passage through the stator 12, which helical path is identical on every occasion in the sense that all the helical paths followed are parallel to one another and therefore have the same pitch P. However, each helical path may be displaced with respect to another one both radially and angularly with respect to each other, and, of course, two major paths are followed being angularly offset by 180° from one another.

[0048] Thus, further passes are made with the tool 100b (it being returned to the inline position for reinsertion in the stator 12), and the passes are shown as circles 1 to 6 in Figure 8a. These passes are intended to clean up the side 16d of the bore 16 to form the sides 14c,d of the stator, but, as can be seen in Figure 8b, the side 16d will comprise a series of ridges defined by the overlapping passes, for example as between passes 4 and 5 in Figure 8b. However, the size of the ridge can be minimized by increasing the number of passes and, for most practical purposes, six is sufficient. Indeed, in one example, with a minor diameter of 27mm and a major diameter of 45mm, and six steps each of approximately 3mm separation between them, the height of the ridge 16d in each case is only about 0.05mm, which is not sufficient to interfere with proper operation of the stator when in use as a pump or motor stator. The order of the passes does not necessarily follow the order of numbers 1 to 6 (or, in fact the order 6 to 1) and it may be that a different order is more efficient. For example, cutting in the order 3, 2, 1, 4, 5, 6 may be preferred for the reason that this maintains the profile 16a of the original bore on the minor diameter for the longest possible time, and so that the shaft 71 can be a close sliding fit therein and provide support for the cutter 80 during its cutting operations. Moreover, when a given pass is completed, for example, pass 3, it would be most convenient to effect the same pass (3) with the same tool in the other lobe or lobes of the stator before changing the cutter to make a different pass (eg 2, or 4).

[0049] Turning to Figure 9, the position of the tool 100b when it is at maximum displacement and is cutting pass 1 (in Figure 8a) is shown within the stator body 12. From this, it can be seen that the cutter head 74 needs to be chamfered at 74a in order to avoid collision with the flank 16e of the profile 14 as it twists behind the cutter head 74. Indeed, the shaft 90 can clearly be seen to be on an axis 20c that is displaced with respect to the axis 20b of the tool 100b. The purpose of this is to minimize the angular deflection of the universal joints 96 when at the maximum deflection of the cutter head 74. It is at this position that the tool is doing most of its cutting of the bore 16c and consequently requires most power to be provided to it. It is well known that universal joints at a large displacement angle absorb substantial power. While it would be feasible to increase the length of the displacement shaft 88, this would only serve to restrict the maximum speed (and thus power) capable of being delivered (all other things being equal) since the whirling threshold is directly linked to the length of this shaft.

[0050] However, the result of the displacement of the bore 92 and consequent displacement of the drive member 90 is that, in order to have the cutting head 74 aligned with the longitudinal axis 20b, (that is, the axis 124 coin-

cident with the axis 20b) the intermediate shaft 88 is actually tilted upwardly. Thus, referring back to Figure 7d, where the axis 124 is shown coincident with the axis 20c of the drive member 90, (that is, with the shafts 84, 88 and 90 all being coincident), the cutting tool 80 is actually positioned to effect pass 4 or 5.

[0051] In Figure 9, the shaft 71 is shown contacting the bore 16a opposite where the cutter tip 83 is engaging the bore 16. Of course, although support is best provided directly opposite the reaction site of the tool and where it is impinging the material being cut, firstly these sites are in several rotational positions about the journal member axis 124, and not just in the plane of the drawing in Figure 9, and secondly, the support is around the entire perimeter of the shaft 71, although in a helix down its length.

[0052] Figure 10 shows an embodiment of the invention wherein the cutter head 74 is configured to have a drive member 126 driving the journal member 84 therein in a different manner to that described with reference to Figures 7a to d. Here the drive member 126 has a gear about an axis 125 which is parallel to said longitudinal axis 20b. The gear drives a corresponding gear 127 on the journal member 84. This allows for a large offset of the cutter rotation axis 124 from the drive axis 20c whilst retaining the power which could be lost by having a large step between the drive 90 and the journal member 84 as shown in Figure 9. However, in Figure 11, a large deflection in intermediate shaft 88 can be seen, but here the cutter 80 is at its minimum offset, ready for passes 4, 5 and 6, at which little material is removed so the loss of power through the large deflection is not an issue.

[0053] In the preferred embodiment, the drive member 126 is connected to the journal member 84 by the gear means as described above. Figure 10 and 11 shows the connection between the journal member 84 and the drive member 126, made using geared wheels 127. The geared wheels 127 are selected to achieve effective power transfer between the members 84,126 whilst locating inside the cutter head 74. However, Figure 12 shows an alternative in which the connection is made by a belt 128 drive. The belt 128 is located on pulley wheels 129 attached to the drive 126 and whirling 84 members.

[0054] Figure 13 shows the drive 126 and journal members 84 configured as part of a hydraulic motor apparatus 130 disposed in the head 74'. Here, the members are arranged with geared wheels 131 which mesh within an oil filled cavity 132. The non-meshing circumference 133 of the geared wheels 131 is exposed to an oil pressure such that oil pumped into a hole 134 in the first side of the apparatus, moves 135 around the non-meshing circumference of the geared wheels 131 to escape from a second hole 136 located at the other side of the apparatus. The movement of the oil around the non-meshing circumference 133 of the geared wheels 131 causes the members to rotate.

[0055] Figure 14 shows an embodiment of the invention wherein driving means 140 is connected directly to the drive member 126 of the cutter head 74. This has the advantage of removing the power loss associated with the transfer of the drive shown in Figure 11 for example. The driving means could be a hydraulic motor, or indeed any other motor that is small enough to locate within the shaft 71.

[0056] Figures 15 to 17 show the invention with an overarm attachment 150 in place. The overarm 150 serves to improve the rigidity of the device when it is configured to cut substantially off axis such as is shown in Figure 15. The overarm 150 is made of a material similar to or the same as that of the shaft and has two arms 151,152 which are separated by a gap in which the cutter is disposed. The arms have holes 153,154 to receive the journal member 84 on bearings 157. The overarm is attached to the shaft 71 by bolts 155 located in bores 156. During attachment, the journal member 84 is passed through one hole 153 in the first arm 151 of the overarm 150, then through the cutter 80 and finally through the hole 154 in the second arm 152 of the overarm 150. In this embodiment, various overarm attachments would be required, each having holes with centers that configure the offset of the cutting axis from the longitudinal axis of the shaft at chosen values. The holes in the overarm 150 may be of the same or different diameter.

[0057] However, in the embodiment shown in Figure 17, the hole 153 in the first arm 151 is shown to be larger than that in the second. This has the purpose of allowing for the journal member 84 to be shaped such that it can pass through the first hole 153 and seat comfortably in the second hole 154. Needle roller bearings 157a, placed in the holes 153,154, enable smooth rotation of the journal member 84 and provide support against the significant radial loads imposed by the cutter. An end cap 158 attaches to the end of said journal member 84 capturing the cutter 80, thrust bearings 157b and limb 152 of the overarm attachment 150, against a shoulder 163 of the member 84.

[0058] The overarm arrangements of Figures 15, 16 and 17 are only feasible with the large offsets of passes 1, 2 and 3 (Figure 8a). However, when passes 4, 5 and 6 are to be made, the arrangement is as described above with reference to Figure 11 because then there is insufficient width above to dispose the overarm. The overarm has two effects, however. The first is that it provides better support for the cutter 80, which is cantilevered in the arrangement of Figures 10 to 14, whereas it is supported on either side with the over arm. Secondly, by extending forwardly as it does, the overarm having pads 162 can bear against an be supported on the minor diameter bore 16a in front of the cutter 80. Both these features assist accurate and secure cutting, and precisely when it is most needed in performing pass 1, 2 and 3. However, when performing passes 4, 5 and 6, as already mentioned above, not so much material is removed and therefore the additional support of the overarm is not so desirable.

[0059] It is to be noted that journal members 84 of Figures 15 and 16 are different in another respect; namely

that while the arrangement of Figure 15 is a stepped head 74 substantially as shown in Figures 10 and 11, in Figure 16 the journal member 84 is as described with reference to Figures 7a to d. Either arrangement is possible.

[0060] While the cutters 82 are shown with a sharp V-shaped point 83, it is likely that, for best results, the point 83 will actually have a small flat, so that adequate longitudinal progress can be made without leaving circumferential grooves in the face of the bore 14.

[0061] Finally, as described above, the cutting head 74 is indexed between different positions and fixed during each pass through the stator body 12. However, an alternative is feasible, which is to provide a drive that moves the cutting head 74 through the different positions illustrated by passes 1 to 6 in Figure 8a as the tool progresses through the stator 12. Several passes could be made through the tool so as to substantially eliminate the ridges 16d. How the cutting head 74 might be moved is within the skill of the person familiar with the art of tool making.

Claims

1. A method of machining the bore (14) of a two-lobe stator (10) for a progressive cavity machine, said bore having a desired profile along a longitudinal axis (20) of the bore comprising a minor (R_0) and a major (R2) diameter and an helically varying radial axis (C_1,C_2) along said longitudinal axis and defining a helix pitch, said profile being defined, at any axial position along said longitudinal axis, by the area swept by a circle of diameter equal to said minor diameter being translated along said radial axis by an equal displacement amount on either side of said longitudinal axis, said method comprising the steps of:

a) providing a tubular stator body (10) with a cylindrical bore (16) centred on said longitudinal axis and of diameter not less than said minor diameter (R_0), and first and second machining devices (100a,b) that are each a close sliding fit on said minor diameter, wherein

b) the first device comprises a milling head (50) on the end of a shaft (40), the milling head mounting a rotary cutter arranged for rotation about an axis (120) transverse said longitudinal axis by a drive mechanism (42) along the shaft;

c) the second device comprises a cutting head (74) on the end of a shaft (71), the cutting head comprising a journal member (84) for mounting a whirling cutter (80) for rotation about an axis (124) substantially parallel to said longitudinal axis but offset therefrom by a selectively variable degree between a minimal and maximal separation of the whirling cutter axis from the longitudinal axis;

d) driving the first device through the bore so that said rotary cutter follows a helical path with said helix pitch, in the process milling a groove (30a) along said path in the stator bore using a sufficiently small diameter rotary cutter that the torque necessary to drive the cutter remains within the capacity of the drive mechanism;

e) angularly offsetting (A,B,C) the rotation axis (120) of the rotary cutter of the first device with respect to the radial axis (120, 130) and again driving the first device through the bore along said helical path, milling a further helical groove (30b,c,d) in the stator bore, also using a sufficiently small diameter rotary cutter that the torque necessary to drive the cutter remains within the capacity of the drive mechanism;

f) extending the depth of cut of the rotary cutter (30e,h) of the first device and repeating steps d) and e) without over cutting the desired profile;

g) driving said second device through the bore so that the whirling cutter (80) follows said helical path with the rotation axis (124) of said whirling cutter intersecting said radial axis (30, 120) and cutting elements (82) of the whirling cutter milling the stator bore to a diameter (R_0) equal said minor diameter, wherein said cutting head (74) is translated along said radial axis (30, 120) by said displacement amount along said longitudinal axis.

2. A machining method as claimed in claim 1, in which said method further includes the step of:

h) said cutting head (74) being set at a radial displacement (1-6) and driven along said helical path before being indexed to a different radial displacement and again driven along said helical path, said process being repeated until said translation is approximately complete, and/or;

the step of

i) said cutting head (74) being arranged to be driven along said radial axis by a radial drive while said second device is within the stator bore.

3. A machining method as claimed in claim 2, in which step i) is employed and said method further includes the step of:

j) said drive being operated to drive said cutting head (74) by said displacement amount along said radial axis (30,120) before indexing said second device (100b) along the helical path and repeating the process until said translation is approximately complete.

4. A machining method as claimed in claims 2 and 3,

in which a combination of steps h) and j) is employed and said method further includes the step of:

k) said cutting head (74) is continuously driven by said displacement amount along said radial axis while said second device (100b) is continuously driven along said helical path, and repeating the process until said translation is approximately complete

5. A machining method as claimed in any preceding claim;
in which said whirling cutter (80) has cutting elements (82) that have V-shaped cutting faces whose points are on a circle of diameter (R_0) equal to said minor diameter; and/or
in which said cylindrical bore (16) of the stator body prior to machining is slightly greater than minor diameter (R1) to define a helical land (16a) that persists throughout the method and is employed to guide said first and second devices (100a,b); and/or in which said first and second devices (100a,b) are each provided with steadies to bear against said helical land and support said heads.

6. A whirling cutter device comprising a cutting head (74) on the end of a shaft (71) having a longitudinal axis (20b) and a diameter thereabout, the cutting head (74) having a journal member (84) on which is mounted a whirling cutter (80) for rotation of the cutter about an axis (124) parallel to said longitudinal axis (20b) but offset therefrom by a selectively variable degree between a minimal and maximal separation of the whirling cutter axis from said longitudinal axis, wherein the shaft has a support surface on said diameter suitable to bear against a material being cut by the whirling cutter device and wherein a helical profile in said material is capable of being cut by the whirling cutter device, said profile having a minor diameter, the said support surface being suitable for bearing on the minor diameter to support said whirling cutter, **characterized in that** the diameter of the cutting path of the cutter (80) when rotating about its axis (124) is equal to the diameter of the shaft (71).

7. A whirling cutter device as claimed in claim 6, in which

said cutting head (74) is mounted on an end face (78) of said shaft (71), said face being perpendicular said longitudinal axis; and preferably
said end face has a groove (76) and said cutter head has a flange (79) for reception in said groove, means enabling fixing of said head in said groove in different positions thereof along the groove.

8. A whirling cutter device as claimed in claim 7, in which said groove (76) and flange (79) are dovetailed.

9. A whirling cutter device as claimed in claim 6, 7 or 8, in which said journal member (84) is driven by a drive member (90) mounted for rotation in said shaft, a pair of universal joints (96) separated by a displacement member (88) enabling offsetting of the axis of rotation of the whirling cutter.

10. A whirling cutter device as claimed in claim 9, wherein said drive between the drive member (90) and the journal member (84) is via an intermediate member (126, 127) disposed in the cutter head, and preferably wherein:

said drive intermediate member is a gear (127) meshing with a gear (127) on said journal member, or
said drive intermediate member is a pulley (129) driving a belt (128) wound around a pulley (129) on said journal member.

11. A whirling cutter device as claimed in any of claims 6 to 8, in which said journal member (84) is driven by a motor (130) mounted on the end of the shaft; and preferably wherein the motor is a hydraulic motor comprising first and second meshing gears (131) located in a cavity (132) supplied with hydraulic fluid, one of said gears being said journal member.

12. A whirling cutter device as claimed in any of claims 6 to 11, wherein the whirling cutter (80) is mounted in a recess of an overarm attachment (150), attached to said end face of said shaft, wherein:

said recess has a first side (151) and a second side (152) perpendicular to said axis of rotation (124) of said cutter, and wherein:

said attachment (150) is one of several attachments providing different ones of said offset position.

13. A whirling cutter device as claimed in claim 12, in which the overarm attachment has a support surface adapted to bear against the material being cut at a point beyond the whirling cutter with respect to said shaft.

14. A method of machining the bore of a lobed stator comprising the steps of:

a) providing the stator (10) with a bore (16) having a minor diameter (R_0);
b) providing a whirling cutter device (100b), which device comprises a cutting head (74) on the end of a shaft (71) having a longitudinal axis

(20b) and a diameter thereabout, the cutting head (74) having a journal member (84) for mounting a
whirling cutter (80) for rotation of the cutter about an axis (124) parallel to said, longitudinal axis (20b) but offset therefrom by a selectively variable degree between a minimal and maximal separation of the whirling cutter axis from said longitudinal axis, and wherein the shaft has a support surface on said diameter;
c) passing the device (100b) through the bore (16) so that the whirling cutter (80) cuts the bore and simultaneously rotating the stator with respect to the device so that the bore cut is helical; and
d) supporting the shaft on the minor diameter of the bore during step c).

15. A method as claimed in claim 14, wherein;
the shaft has substantially the same diameter as the bore and is a close sliding fit therein; and/or;
the method is repeated at a different rotational start position of the whirling cutter device with respect to the stator, whereby a plurality of lobes is cut; and/or
the method is repeated at different offsets of the whirling cutter; and/or
a whirling cutter device as claimed in any of claims 6 to 13 is employed.

Patentansprüche

1. Verfahren zum maschinellen Fertigen der Bohrung (14) eines Zweikammerstators (10) für eine Exzenterschneckenarbeitsmaschine, wobei die Bohrung entlang einer Längsachse (20) der Bohrung ein gewünschtes Profil aufweist, das einen kleineren (R_0) und einen größeren (R_2) Durchmesser und eine spiralförmig variierende Radialachse (C_1, C_2) entlang der Längsachse umfasst und eine Spiralensteigung definiert, wobei das Profil auf jeder Position entlang der Längsachse durch den Bereich definiert ist, der von einem Kreis überlagert ist, dessen Durchmesser dem kleineren Durchmesser entspricht, verschoben entlang der Radialachse durch ein gleiches Versetzungsmaß auf beiden Seiten der Längsachse, wobei das Verfahren die folgenden Schritte beinhaltet:

a) Vorsehen eines rohrförmigen Statorkörpers (10) mit einer zylindrischen Bohrung (16), die auf der Längsachse zentriert ist und einen Durchmesser von nicht weniger als der kleinere Durchmesser (R_0) aufweist, und erste und zweite Vorrichtungen zur maschinellen Fertigung (100a, b), die jeweils einen engen Gleitsitz auf dem kleineren Durchmesser darstellen, wobei
b) die erste Vorrichtung einen Fräskopf (50) am Ende einer Welle (40) umfasst, wobei an dem Fräskopf ein Rotationsschneider befestigt ist, der zur Rotation um eine quer zu der Längsachse verlaufende Achse (120) durch einen Antriebsmechanismus (42) entlang der Welle angeordnet ist;
c) die zweite Vorrichtung einen Schneidkopf (74) am Ende einer Welle (71) umfasst, wobei der Schneidkopf ein Bolzenglied (84) zum Befestigen eines Wirbelschneiders (80) zur Rotation um eine Achse (124) umfasst, welche im Wesentlichen parallel zu der Längsachse verläuft, jedoch durch einen auswählbar variablen Grad zwischen einer minimalen und maximalen Trennung der Wirbelschneiderachse von der Längsachse von dieser versetzt ist;
d) Antreiben der ersten Vorrichtung durch die Bohrung, sodass der Rotationsschneider einer spiralförmigen Bahn mit der Spiralensteigung folgt, wobei entlang der spiralförmigen Bahn in der Statorbohrung unter Verwendung eines Rotationsschneiders mit einem Durchmesser, der ausreichend klein ist, dass das Drehmoment, das zum Antreiben des Schneiders notwendig ist, innerhalb der Kapazität des Antriebsmechanismus bleibt, eine Rille (30a) gefräst wird;
e) winkliges Versetzen (A, B, C) der Rotationsachse (120) des Rotationsschneiders der ersten Vorrichtung in Bezug auf die Radialachse (120, 130) und erneutes Antreiben der ersten Vorrichtung durch die Bohrung entlang der spiralförmigen Bahn, wobei ebenfalls unter Verwendung eines Rotationsschneiders mit einem ausreichend kleinen Durchmesser, dass das Drehmoment, das zum Antreiben des Schneiders notwendig ist, innerhalb der Kapazität des Antriebsmechanismus bleibt, eine weitere spiralförmige Rille (30b, c, d) in der Statorbohrung gefräst wird;
f) Erweitern der Tiefe des Schnitts des Rotationsschneiders (30e, h) der ersten Vorrichtung und Wiederholen der Schritte d) und e) ohne Überschneiden des gewünschten Profils;
g) Antreiben der zweiten Vorrichtung durch die Bohrung, sodass der Wirbelschneider (80) der spiralförmigen Bahn mit der Rotationsachse (124) des Wirbelschneiders folgt, welche die Radialachse (30, 120) kreuzt, und Schneidelemente (82) des Wirbelschneiders, welcher die Statorbohrung auf einen Durchmesser (R_0) fräst, der dem kleineren Durchmesser entspricht, wobei der Schneidkopf (74) durch das Versetzungsmaß entlang der Längsachse entlang der Radialachse (30, 120) verschoben wird.

2. Maschinelles Fertigungsverfahren nach Anspruch 1, wobei das Verfahren ferner die folgenden Schritte beinhaltet:

h) der Schneidkopf (74) wird bei einer radialen Versetzung (1-6) eingestellt und entlang der spiralförmigen Bahn angetrieben, bevor er zu einer anderen radialen Versetzung weitergeschaltet und erneut entlang der spiralförmigen Bahn angetrieben wird, wobei der Vorgang wiederholt wird, bis die Verschiebung annähernd vollständig ist, und/oder

den folgenden Schritt:

i) der Schneidkopf (74) ist derart angeordnet, dass er durch einen Radialantrieb entlang der Radialachse angetrieben wird, während sich die zweite Vorrichtung innerhalb der Statorbohrung befindet.

3. Maschinelles Fertigungsverfahren nach Anspruch 2, in welchem Schritt i) umgesetzt wird und das Verfahren ferner den folgenden Schritt beinhaltet:

j) der Antrieb wird derart betrieben, dass der Schneidkopf (74) durch das Verschiebungsmaß entlang der Radialachse (30, 120) angetrieben wird, bevor die zweite Vorrichtung (100b) entlang der spiralförmigen Bahn weitergeschaltet wird, und der Vorgang wiederholt wird, bis die Verschiebung annähernd vollständig ist.

4. Maschinelles Fertigungsverfahren nach Anspruch 2 oder 3, in welchem eine Kombination aus den Schritten h) und j) umgesetzt wird, und wobei das Verfahren ferner den folgenden Schritt beinhaltet:

k) der Schneidkopf (74) wird durch das Verschiebungsmaß entlang der Radialachse kontinuierlich angetrieben, während die zweite Vorrichtung (100b) kontinuierlich entlang der spiralförmigen Bahn angetrieben wird, und der Vorgang wird wiederholt, bis die Verschiebung annähernd vollständig ist.

5. Maschinelles Fertigungsverfahren nach einem der vorausgehenden Ansprüche;
in welchem der Wirbelschneider (80) Schneidelemente (82) umfasst, die V-förmige Schneidflächen aufweisen, deren Punkte sich auf einem Kreis mit einem Durchmesser (R_0) befinden, der dem kleineren Durchmesser entspricht; und/oder
in welchem die zylindrische Bohrung (16) des Statorkörpers vor der maschinellen Bearbeitung etwas größer als der kleinere Durchmesser (R_0) ist, um eine Spiralstegfläche (16a) zu defieren, welche über das gesamte Verfahren hinweg besteht und gebraucht wird, um die erste und zweite Vorrichtung (100a, b) zu führen; und/oder
in welchem die erste und zweite Vorrichtung (100a,b) jeweils mit Lünetten vorgesehen sind, um an der Spiralstegfläche anzuliegen und die Köpfe zu stützen.

6. Wirbelschneidervorrichtung, umfassend einen Schneidkopf (74) am Ende der Welle (71) mit einer Längsachse (20b) und einen Durchmesser da herum, wobei der Schneidkopf (74) ein Bolzenglied (84) umfasst, an dem ein Wirbelschneider (80) zur Rotation des Schneiders um eine Achse (124) parallel zu der Längsachse (20b), jedoch um einen auswählbar variablen Grad zwischen einer minimalen und maximalen Trennung der Wirbelschneiderachse von der Längsachse davon versetzt befestigt ist, wobei die Welle eine Stützfläche an dem Durchmesser umfasst, die dafür geeignet ist, an einem von der Wirbelschneidervorrichtung geschnittenen Material anzuliegen, und wobei ein spiralförmiges Profil in dem Material in der Lage ist, von der Wirbelschneidervorrichtung geschnittenen zu werden, wobei das Profil einen kleineren Durchmesser aufweist, wobei die Stützfläche dafür geeignet ist, an dem kleineren Durchmesser anzuliegen, um den Wirbelschneider zu stützen, **dadurch gekennzeichnet, dass** der Durchmesser der Schneidbahn des Schneiders (80) bei der Rotation um dessen Achse (124) dem Durchmesser der Welle (71) entspricht.

7. Wirbelschneidervorrichtung nach Anspruch 6, wobei der Schneidkopf (74) an einer Endfläche (78) der Welle (71) befestigt ist, wobei die Fläche senkrecht zu der Längsachse verläuft; und vorzugsweise wobei
die Endfläche eine Kerbe (76) und der Schneidkopf einen Flansch (79) zum Aufnehmen in der Kerbe, Mittel zum Ermöglichen des Befestigens des Kopfs in der Kerbe in verschiedenen Positionen davon entlang der Kerbe aufweist.

8. Wirbelschneidervorrichtung nach Anspruch 7, wobei die Kerbe (76) und der Flansch (79) eingeschwalbt sind.

9. Wirbelschneidervorrichtung nach Anspruch 6, 7 oder 8, wobei das Bolzenglied (84) angetrieben wird von einem Antriebselement (90), das zur Rotation in der Welle gefestigt ist, einem Paar Wellengelenken (96), die durch ein Versetzungsglied (88) getrennt sind, das die Versetzung der Rotationsachse des Wirbelschneiders ermöglicht.

10. Wirbelschneidervorrichtung nach Anspruch 9, wobei der Antrieb zwischen dem Antriebselement (90) und dem Bolzenglied (84) über ein Zwischenglied (126, 127) erfolgt, das in dem Schneidkopf angeordnet ist, und vorzugsweise wobei:

es sich bei dem Antriebszwischenglied um ein Getriebe (127) handelt, das mit einem Getriebe

(127) an dem Bolzenglied eingreift, oder es sich bei dem Antriebszwischenglied um eine Treibrolle (129) handelt, die einen Riemen (128) antreibt, welcher um eine Treibrolle (129) an dem Bolzenglied gewickelt ist.

11. Wirbelschneidervorrichtung nach einem der Ansprüche 6 bis 8, wobei das Bolzenglied (84) von einem am Ende der Welle befestigten Motor (130) angetrieben wird, und vorzugsweise wobei der Motor ein Hydraulikmotor ist, umfassend erste und zweite Gegenräder (131), die in einer mit Hydraulikfluid versorgten Vertiefung (132) angeordnet sind, wobei es sich bei einem der Räder um das Bolzenglied handelt.

12. Wirbelschneidervorrichtung nach einem der Ansprüche 6 bis 11, wobei der Wirbelschneider (80) in einer Aussparung eines Gegenhalteransatzstücks (150), welches an der Endfläche der Welle angebracht ist, befestigt ist, wobei:

die Aussparung eine erste Seite (151) und eine zweite Seite (152) senkrecht zu der Rotationsachse (124) des Schneiders umfasst, und wobei:

es sich bei dem Ansatzstück (150) um eines von mehreren Ansatzstücken handelt, die verschiedene der Versetzungspositionen bereitstellen.

13. Wirbelschneidervorrichtung nach Anspruch 12, wobei das Gegenhalteransatzstück eine Stützfläche aufweist, die dazu ausgelegt ist, an dem Material anzuliegen, das an einem Punkt hinter dem Wirbelschneider in Bezug auf die Welle geschnitten wird.

14. Verfahren zur maschinellen Fertigung der Bohrung eines Kammerstators, das die folgenden Schritte umfasst:

a) Vorsehen des Stators (10) mit einer Bohrung (16), welche einen kleineren Durchmesser (R_0) aufweist;
b) Vorsehen einer Wirbelschneidervorrichtung (100b), wobei die Vorrichtung einen Schneidkopf (74) am Ende einer Welle (71) mit einer Längsachse (20b) und einem Durchmesser da herum umfasst, wobei der Schneidkopf (74) ein Bolzenglied (84) zum Befestigen eines Wirbelschneiders (80) zur Rotation des Schneiders um eine Achse (124) umfasst, die parallel zu der Längsachse (20b) verläuft, jedoch um einen auswählbar variablen Grad zwischen einer minimalen und maximalen Trennung der Wirbelschneiderachse von der Längsachse davon versetzt ist, und wobei die Welle eine Stützfläche an dem Durchmesser aufweist;
c) Passieren der Vorrichtung (100b) durch die Bohrung (16), sodass der Wirbelschneider (80) die Bohrung herausschneidet und gleichzeitig den Stator in Bezug auf die Vorrichtung rotiert, sodass die Bohrung spiralförmig herausgeschnitten wird; und
d) Stützen der Welle auf dem kleineren Durchmesser der Bohrung während Schritt c).

15. Verfahren nach Anspruch 14, wobei
die Welle im Wesentlichen den gleichen Durchmesser wie die Bohrung aufweist und einen engen Gleitsitz darin darstellt; und/oder
das Verfahren bei einer anderen Rotationsstartposition der Wirbelschneidervorrichtung in Bezug auf den Stator wiederholt wird, wobei eine Vielzahl von Kammern herausgeschnitten wird;
und/oder
das Verfahren bei verschiedenen Versetzungen des Wirbelschneiders wiederholt wird; und/oder eine Wirbelschneidervorrichtung nach einem der Ansprüche 6 bis 13 gebraucht wird.

Revendications

1. Procédé d'usinage de l'alésage (14) d'un stator à deux lobes (10) pour machine à cavité progressive, ledit alésage possédant un profil désiré le long d'un axe longitudinal (20) de l'alésage comprenant un petit diamètre (R_0) et un grand diamètre (R_2) et un axe radial (C_1, C_2) variant hélicoïdalement le long dudit axe longitudinal et définissant un pas d'hélice, ledit profil étant défini, en une quelconque position axiale le long dudit axe longitudinal, par l'aire balayée par un cercle de diamètre égal audit petit diamètre étant translaté le long dudit axe radial par une même amplitude de déplacement de part et d'autre dudit axe longitudinal, ledit procédé comprenant les étapes de :

a) obtention d'un corps de stator tubulaire (10) présentant un alésage cylindrique (16) centré sur ledit axe longitudinal et de diamètre supérieur ou égal audit petit diamètre (R_0), et des premier et second dispositifs d'usinage (100a,b) qui sont chacun un ajustement coulissant étroit sur ledit petit diamètre :
b) le premier dispositif comprenant une tête de fraisage (50) sur l'extrémité d'un arbre (40), la tête de fraisage étant munie d'une lame rotative conçue pour tourner autour d'un axe (120) transversal audit axe longitudinal au moyen d'un mécanisme d'entraînement (42) le long de l'arbre ;
c) le second dispositif comprenant une tête coupante (74) sur l'extrémité de l'arbre (71), la tête coupante comprenant un élément de tourillon

(84) pour le montage d'une lame tournoyante (80) destinée à tourner autour d'un axe (124) sensiblement parallèle audit axe longitudinal mais déporté par rapport à celui-ci d'un degré sélectivement variable entre une séparation minimale et une séparation maximale de l'axe de lame tournoyante d'avec l'axe longitudinal ;
d) entraînement du premier dispositif à travers l'alésage de façon à ce que ladite lame rotative suive un trajet hélicoïdal avec ledit pas d'hélice, dans le procédé de fraisage d'une gorge (30a) le long dudit trajet dans l'alésage de stator à l'aide d'une lame rotative de diamètre suffisamment petit pour que le couple nécessaire à l'entraînement de la lame reste dans les capacités du mécanisme d'entraînement ;
e) déportation angulaire (A, B, C) de l'axe de rotation (120) de la lame rotative du premier dispositif par rapport à l'axe radial (120, 130) et de nouveau entraînement du premier dispositif à travers l'alésage le long dudit trajet hélicoïdal, fraisage d'une autre gorge hélicoïdale (30b,c,d) dans l'alésage de stator, à l'aide également d'une lame rotative de diamètre suffisamment petit pour que le couple nécessaire à l'entraînement de la lame reste dans les capacités du mécanisme d'entraînement ;
f) extension de la profondeur de coupe de la lame rotative (30e,h) du premier dispositif et répétition des étapes d) et e) sans couper au-delà du profil désiré ;
g) entraînement dudit second dispositif à travers l'alésage de façon à ce que la lame tournoyante (80) suive ledit trajet hélicoïdal avec l'axe de rotation (124) de ladite lame tournoyante intersectant ledit axe radial (30, 120) et les éléments coupants (82) de la lame tournoyante fraisant l'alésage de stator à un diamètre (R_0) égal audit petit diamètre, ladite tête coupante (74) étant translatée le long dudit axe radial (30, 120) de ladite amplitude de déplacement le long dudit axe longitudinal.

2. Procédé d'usinage selon la revendication 1, ledit procédé comprenant en outre l'étape de :

h) réglage de ladite tête coupante (74) à un déplacement radial (1-6) et entraînée le long dudit trajet hélicoïdal avant d'être indexée sur un déplacement radial différent et de nouveau entraînée le long dudit trajet hélicoïdal, ledit procédé étant répété jusqu'à ce que ladite translation soit approximativement achevée, et/ou ;

l'étape de

i) agencement de ladite tête coupante (74) afin d'être entraînée le long de l'axe radial par un entraînement radial pendant que ledit second dispositif est à l'intérieur de l'alésage de stator.

3. Procédé d'usinage selon la revendication 2, l'étape i) étant employée et ledit procédé comprenant en outre l'étape de :

j) actionnement dudit entraînement afin d'entraîner ladite tête coupante (74) de ladite amplitude de déplacement le long dudit axe radial (30, 120) avant l'indexation dudit second dispositif (100b) le long du trajet hélicoïdale et répétition du procédé jusqu'à ce que ladite translation soit approximativement achevée.

4. Procédé d'usinage selon les revendications 2 et 3, une combinaison des étapes h) et j) étant utilisée et ledit procédé comprenant en outre l'étape de :

k) entraînement continu de ladite tête coupante (74) de ladite amplitude de déplacement le long dudit axe radial pendant que ledit second dispositif (100b) est entraîné en continu le long dudit trajet hélicoïdal, et répétition du procédé jusqu'à ce que ladite translation soit approximativement achevée.

5. Procédé d'usinage selon l'une quelconque des revendications précédentes ;
ladite lame tournoyante (80) possédant des éléments coupants (82) qui possèdent des faces coupantes en forme de V dont les points sont sur un cercle de diamètre (R_0) égal audit petit diamètre ; et/ou
ledit alésage cylindrique (16) du corps de stator avant l'usinage étant légèrement supérieur au petit diamètre (R_0) afin de définir un cordon hélicoïdal (16a) qui persiste tout au long du procédé et est utilisé pour guider lesdits premier et second dispositifs (100a,b) ; et/ou
lesdits premier et second dispositifs (100a,b) étant chacun équipés de bras de support afin de venir prendre appui contre ledit cordon hélicoïdal et supporter lesdites têtes.

6. Dispositif à lame tournoyante comprenant une tête coupante (74) sur l'extrémité de l'arbre (71) possédant un axe longitudinal (20b) et un diamètre autour de celui-ci, la tête coupante (74) possédant un élément de tourillon (84) sur lequel est monté une lame tournoyante (80) pour la rotation de la lame autour d'un axe (124) parallèle audit axe longitudinal (20b) mais déporté par rapport à celui-ci d'un degré sélectivement variable entre une séparation minimale et une séparation maximale de l'axe de lame tournoyante d'avec ledit axe longitudinal, ledit arbre possédant une surface de support sur ledit diamètre appropriée pour venir en appui contre un matériau cou-

pé par le dispositif à lame tournoyante et un profil hélicoïdal étant capable d'être coupé dans ledit matériau par le dispositif à lame tournoyante, ledit profil possédant un petit diamètre, ladite surface de support étant appropriée pour prendre appui sur le petit diamètre afin de supporter ladite lame tournoyante, **caractérisé en ce que** le diamètre du trajet de coupe de la lame (80) lorsque celle-ci est en rotation autour de son axe (124) est égal au diamètre de l'arbre (71).

7. Dispositif à lame tournoyante selon la revendication 6, ladite tête coupante (74) étant montée sur la face d'extrémité (78) dudit arbre (71), ladite face étant perpendiculaire audit axe longitudinal ; et de préférence ladite face d'extrémité possédant une rainure (76) et ladite tête coupante possédant un rebord (79) destiné à être reçu dans ladite rainure, un moyen permettant la fixation de ladite tête dans ladite rainure dans différentes positions de celle-ci le long de la rainure.

8. Dispositif à lame tournoyante selon la revendication 7, ladite rainure (76) et ledit rebord (79) étant en queue d'aronde.

9. Dispositif à lame tournoyante selon la revendication 6, 7 ou 8, ledit élément de tourillon (84) étant entraîné par un élément d'entraînement (90) monté pour tourner dans ledit arbre, une paire de joints universels (96) séparés par un élément de déplacement (88) permettant la déportation de l'axe de rotation de la lame tournoyante.

10. Dispositif à lame tournoyante selon la revendication 9, ledit entraînement entre l'élément d'entraînement (90) et l'élément de tourillon (84) s'effectuant par l'intermédiaire d'un élément intermédiaire (126, 127) disposé dans la tête coupante, et de préférence :

ledit élément intermédiaire d'entraînement étant un engrenage (127) s'engrenant avec un engrenage (127) dudit élément de tourillon, ou
ledit élément intermédiaire d'entraînement étant une poulie (129) entraînant une courroie (128) enroulée autour d'une poulie (129) sur ledit élément de tourillon.

11. Dispositif à lame tournoyante selon l'une quelconque des revendications 6 à 8, ledit élément de tourillon (84) étant entraîné par un moteur (130) monté sur l'extrémité de l'arbre ; et de préférence ledit moteur étant un moteur hydraulique comprenant des premier et second engrenages engrenés (131) situés dans une cavité (132) alimentée en fluide hydraulique, l'un desdits engrenages étant ledit élément de tourillon.

12. Dispositif à lame tournoyante selon l'une quelconque des revendications 6 à 11, ladite lame tournoyante (80) étant montée dans un creux d'une fixation de bras de support (150), fixée à ladite face d'extrémité dudit arbre ;
ledit creux possédant un premier côté (151) et un second côté (152) perpendiculaires audit axe de rotation (124) de ladite lame, et
ladite fixation (150) étant l'une parmi les nombreuses fixations fournissant les différentes positions de ladite position de déportation.

13. Dispositif à lame tournoyante selon la revendication 12, ladite fixation de bras de support possédant une surface de support conçue pour venir en appui contre le matériau coupé en un point situé au-delà de la lame tournoyante par rapport audit arbre.

14. Procédé d'usinage de l'alésage d'un stator lobé comprenant les étapes de :

a) obtention du stator (10) avec un alésage (16) possédant un petit diamètre (R_0) ;
b) obtention d'un dispositif à lame tournoyante (100b), ledit dispositif comprenant une tête coupante (74) sur l'extrémité de l'arbre (71) possédant un axe longitudinal (20b) et un diamètre autour de celui-ci, ladite tête coupante (74) possédant un élément de tourillon (84) pour le montage d'une lame tournoyante (80) pour la rotation de la lame autour d'un axe (124) parallèle audit axe longitudinal (20b) mais déporté par rapport à celui-ci d'un degré sélectivement variable entre une séparation minimale et une séparation maximale de l'axe de lame tournoyante d'avec ledit axe longitudinal, et ledit arbre possédant une surface de support sur ledit diamètre ;
c) passage du dispositif (100b) à travers l'alésage (16) de façon à ce que la lame tournoyante (80) coupe l'alésage et simultanément fait tourner le stator par rapport au dispositif de façon à ce que la coupe d'alésage soit hélicoïdale ; et
d) soutien de l'arbre sur le petit diamètre de l'alésage durant l'étape c).

15. Procédé selon la revendication 14, ledit arbre possédant sensiblement le même diamètre que l'alésage et étant un ajustement coulissant étroit de celui-ci ; et/ou ;
le procédé étant répété pour une position initiale de rotation différente du dispositif à lame tournoyante par rapport au stator ce qui permet la coupe d'une pluralité de lobes ; et/ou le procédé étant répété pour différentes déportations de la lame tournoyante ; et/ou un dispositif à lame tournoyante selon l'une quelconque des revendications 6 à 13 étant utilisé.

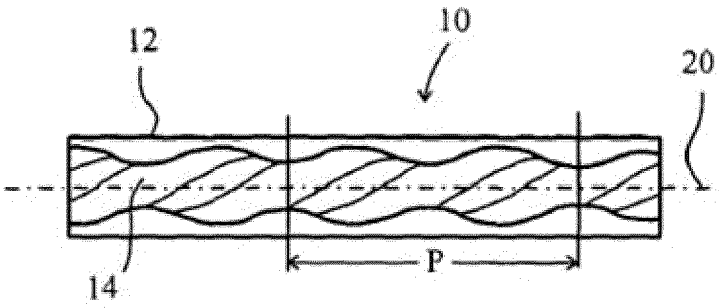


Fig. 1a

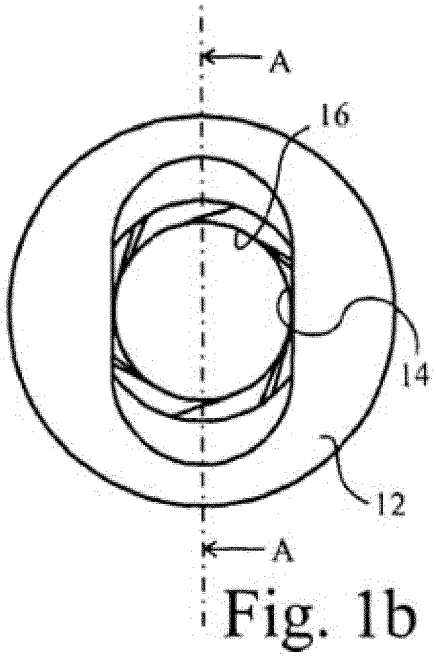


Fig. 1b

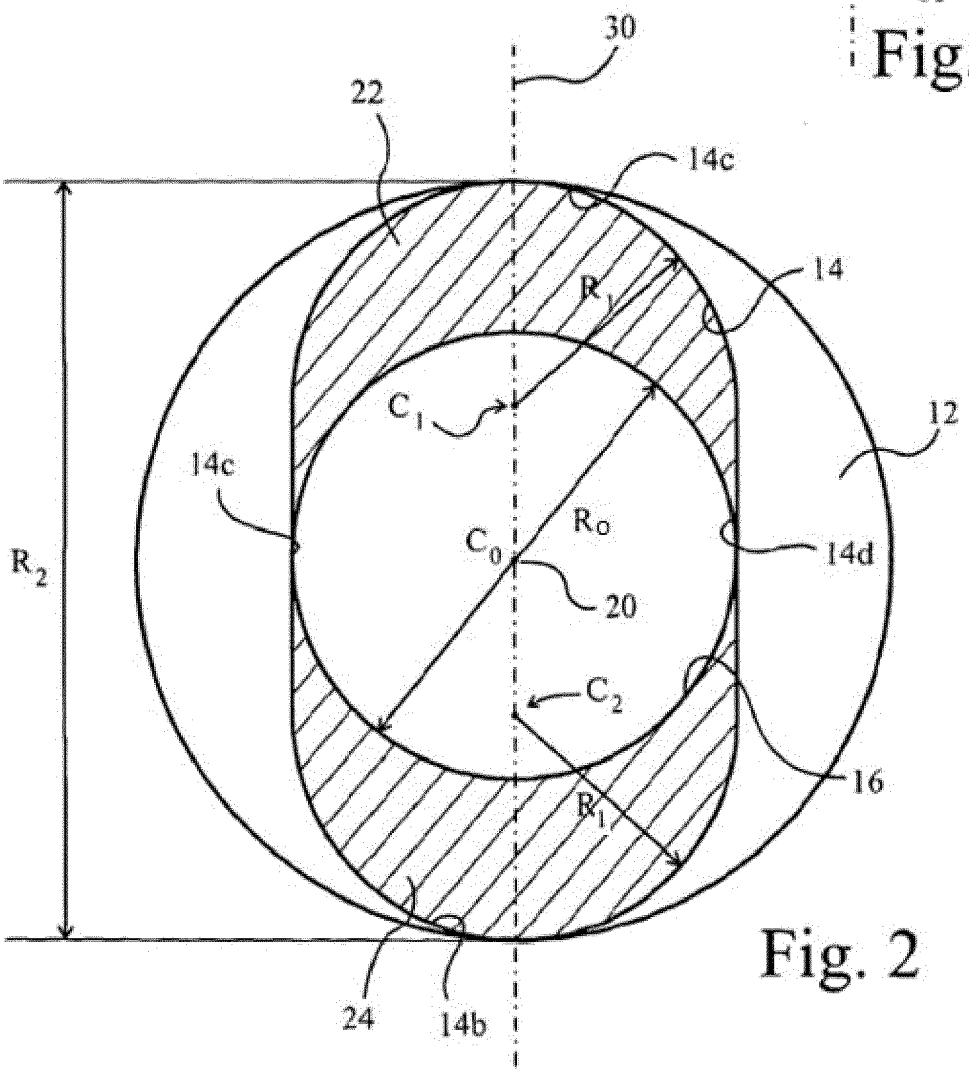


Fig. 2

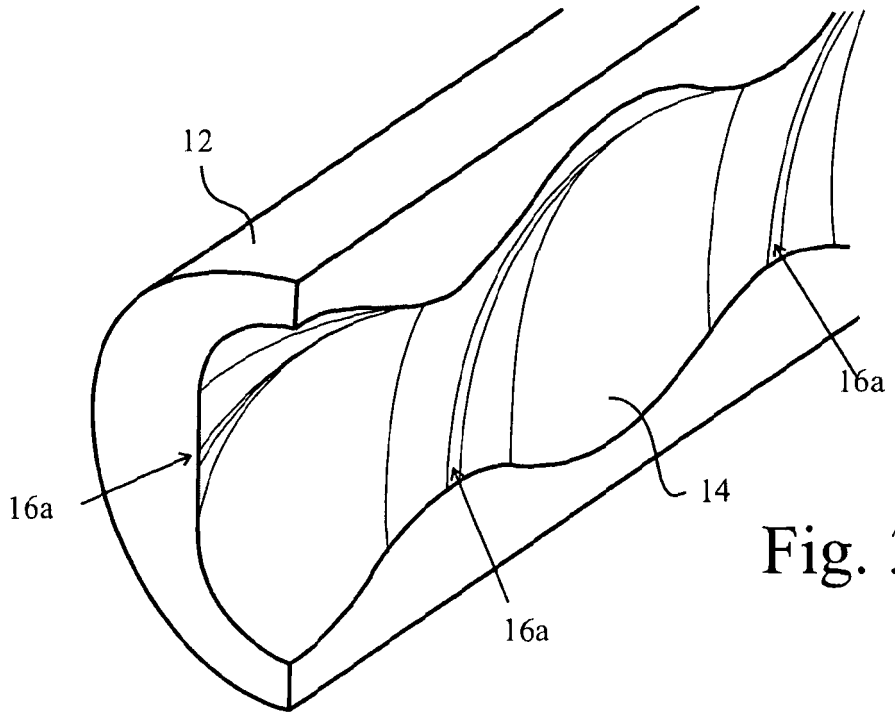

12
16a
16a
14
16a

Fig. 3

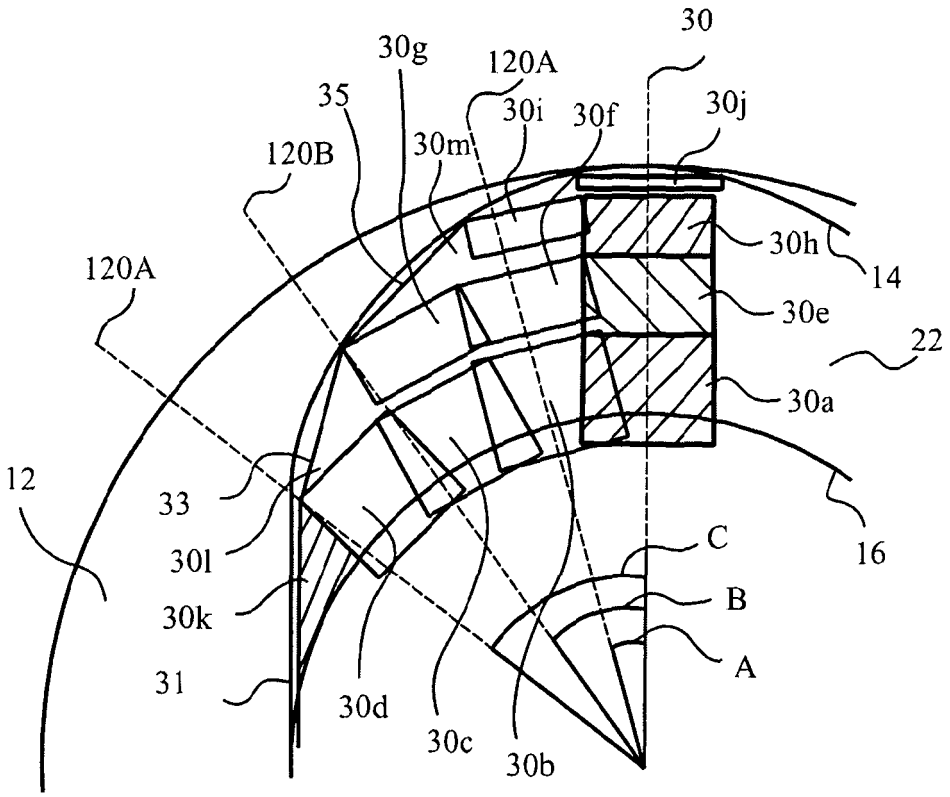

30
30g
120A
35
30i
30f
30j
120B
30m
30h
14
120A
30e
22
30a
12
33
16
C
30l
B
30k
A
31
30d
30c
30b

Fig. 4

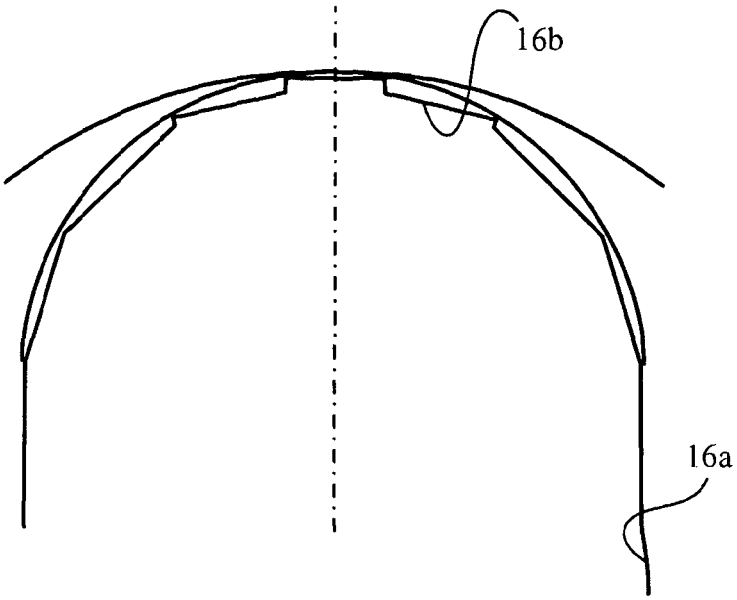


Fig. 5

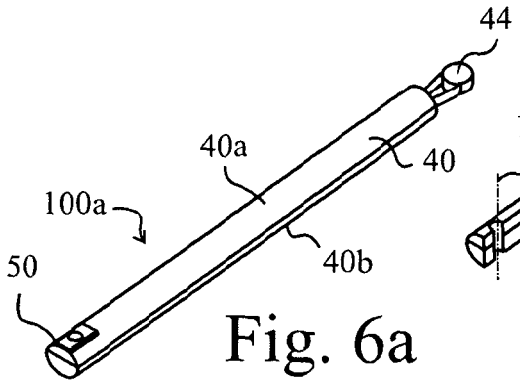


Fig. 6a

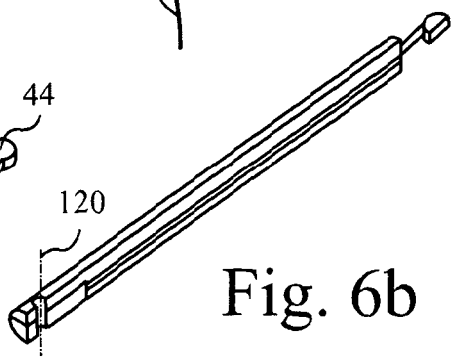


Fig. 6b

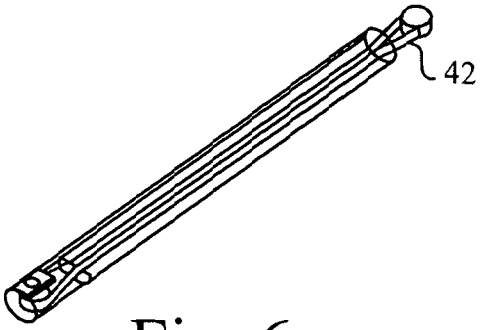


Fig. 6c

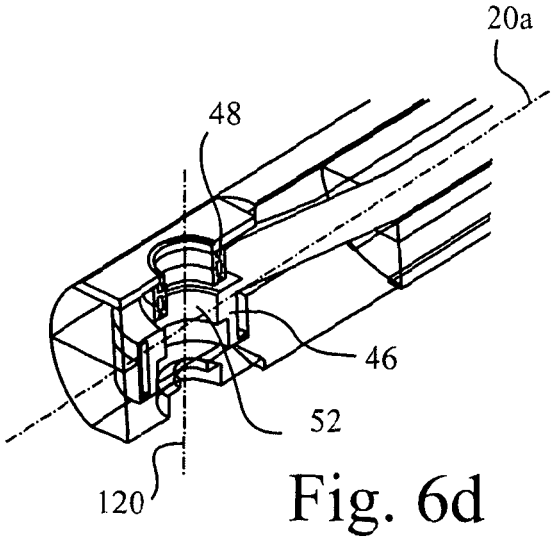


Fig. 6d

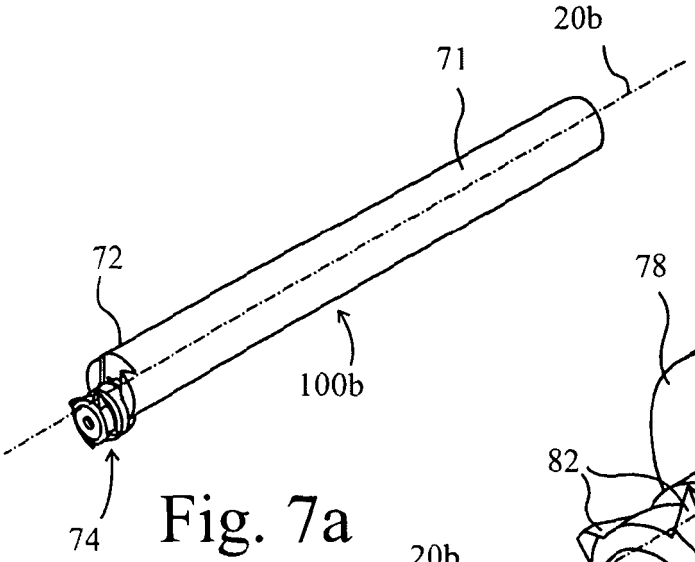


Fig. 7a

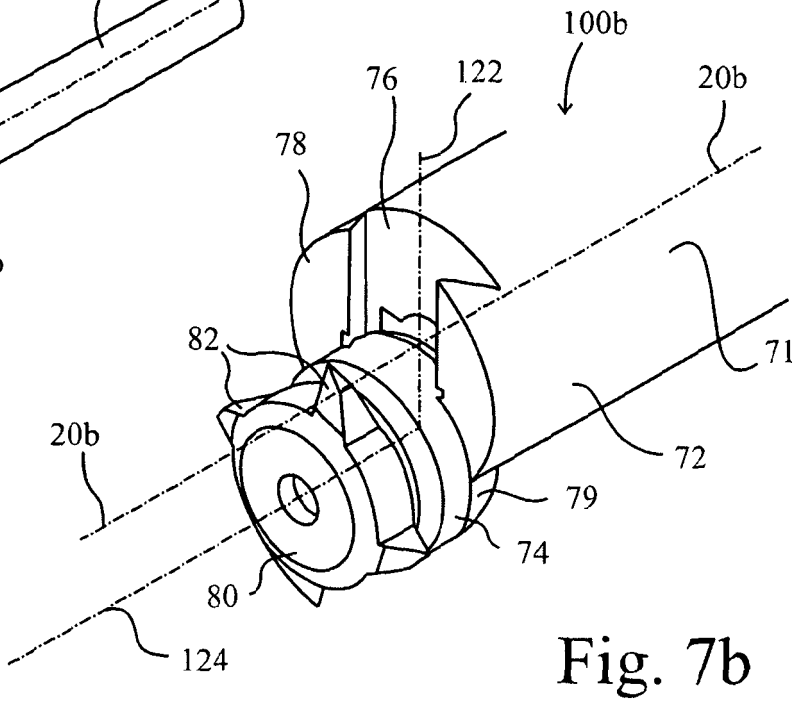


Fig. 7b

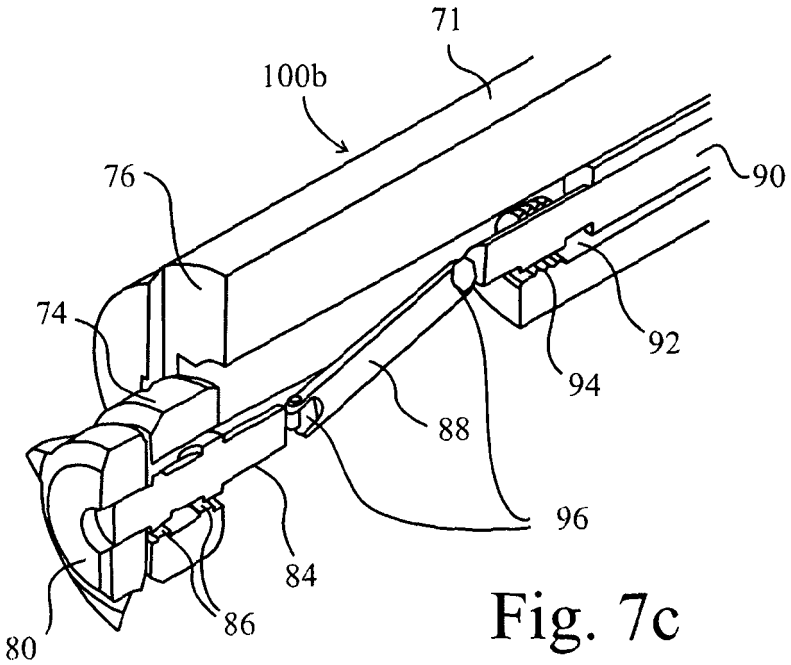


Fig. 7c

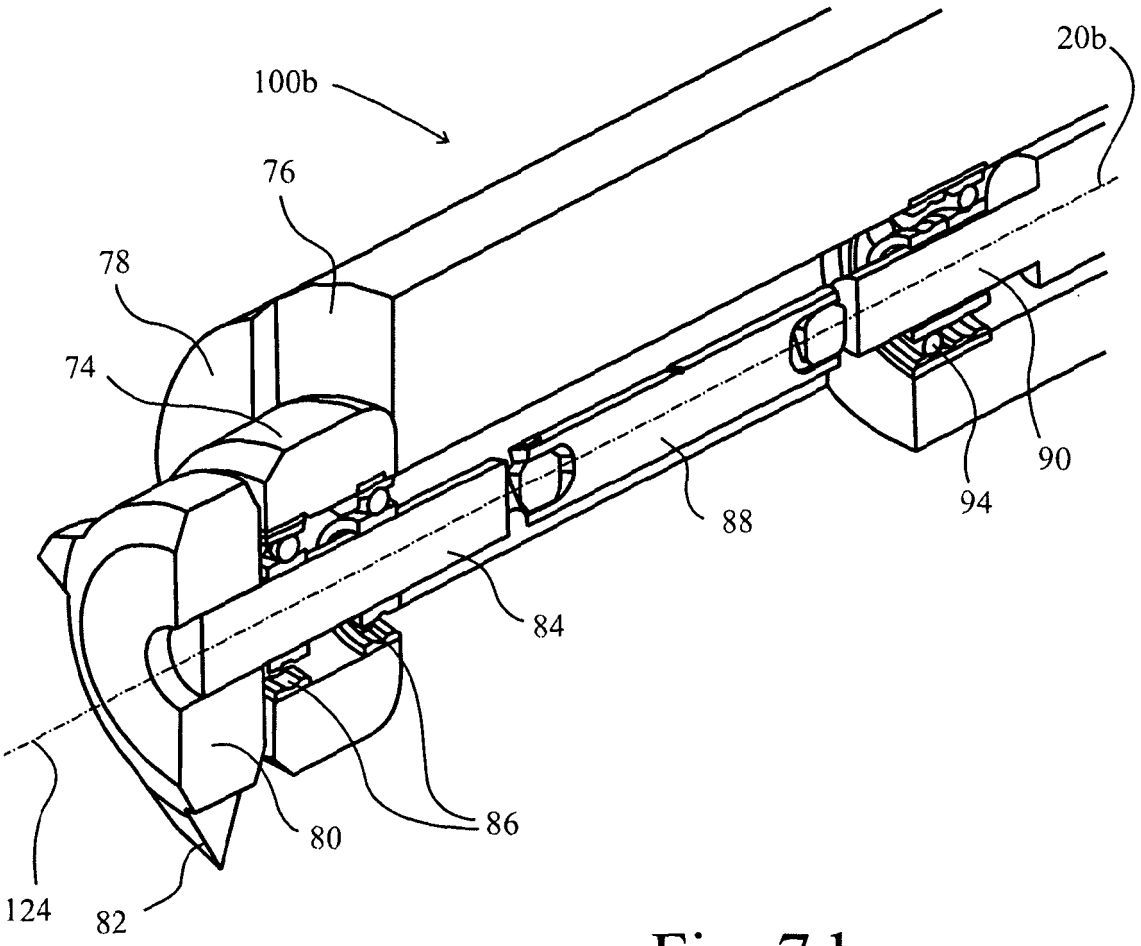


Fig. 7d

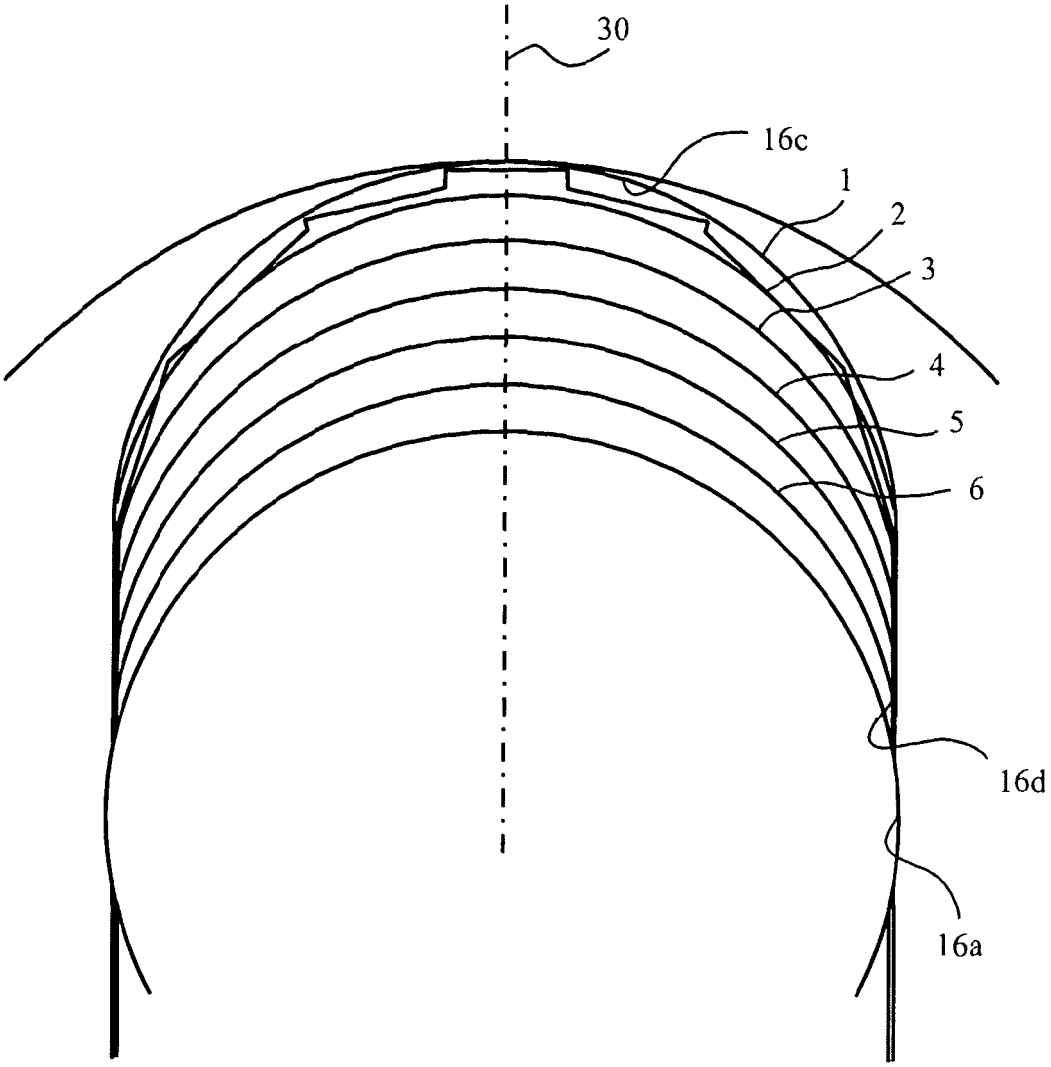


Fig. 8a

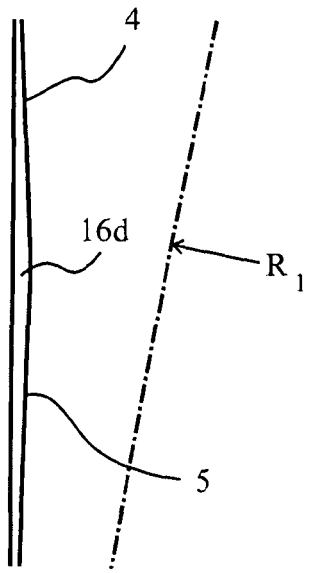

4
16d
R_1
5

Fig. 8b

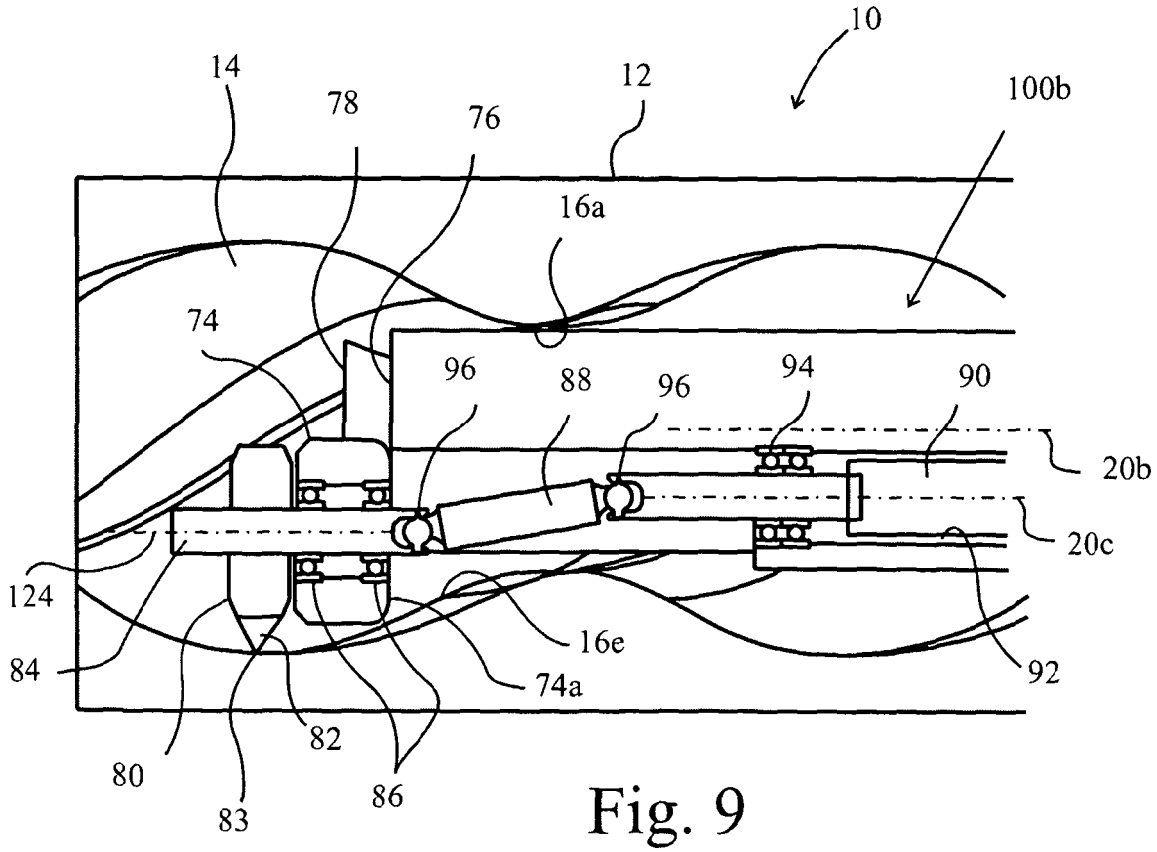

10
14
78
76
12
100b
16a
74
96
88
96
94
90
20b
20c
124
84
16e
74a
92
80
82
83
86

Fig. 9

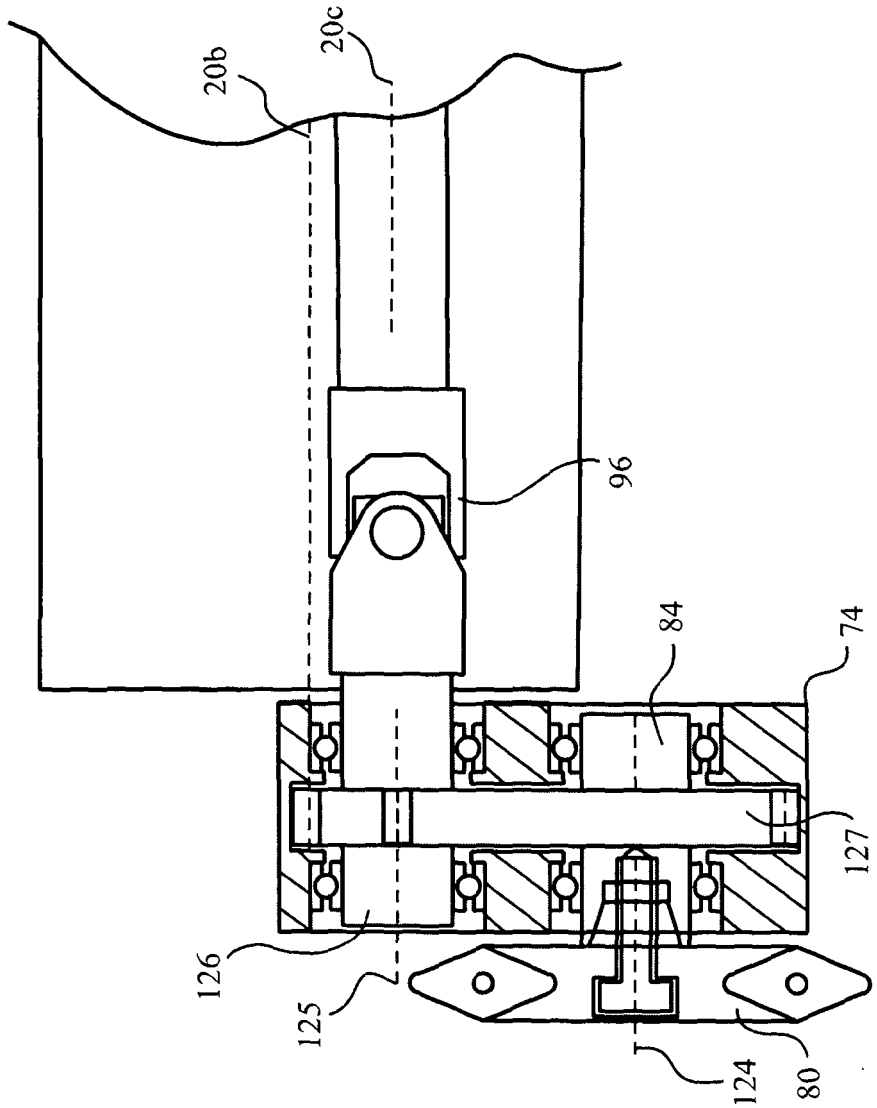


Fig. 10

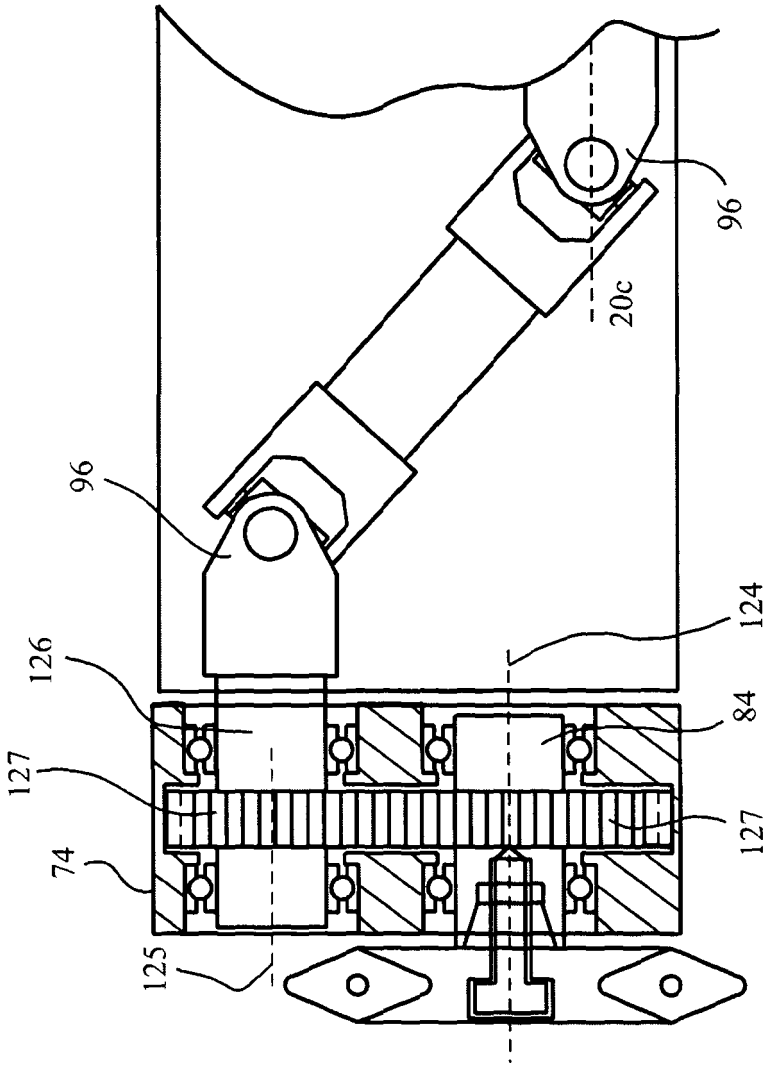


Fig. 11

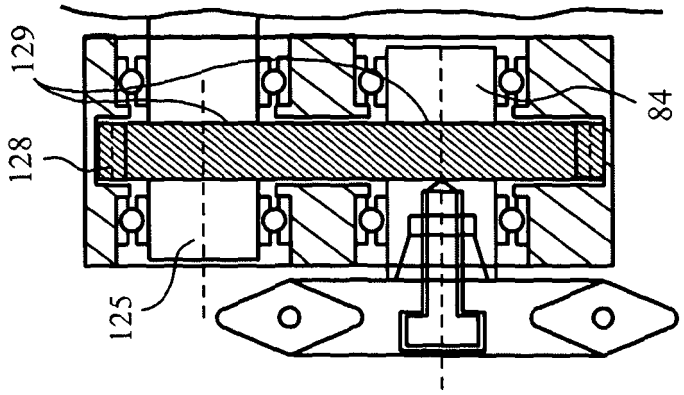


Fig. 12

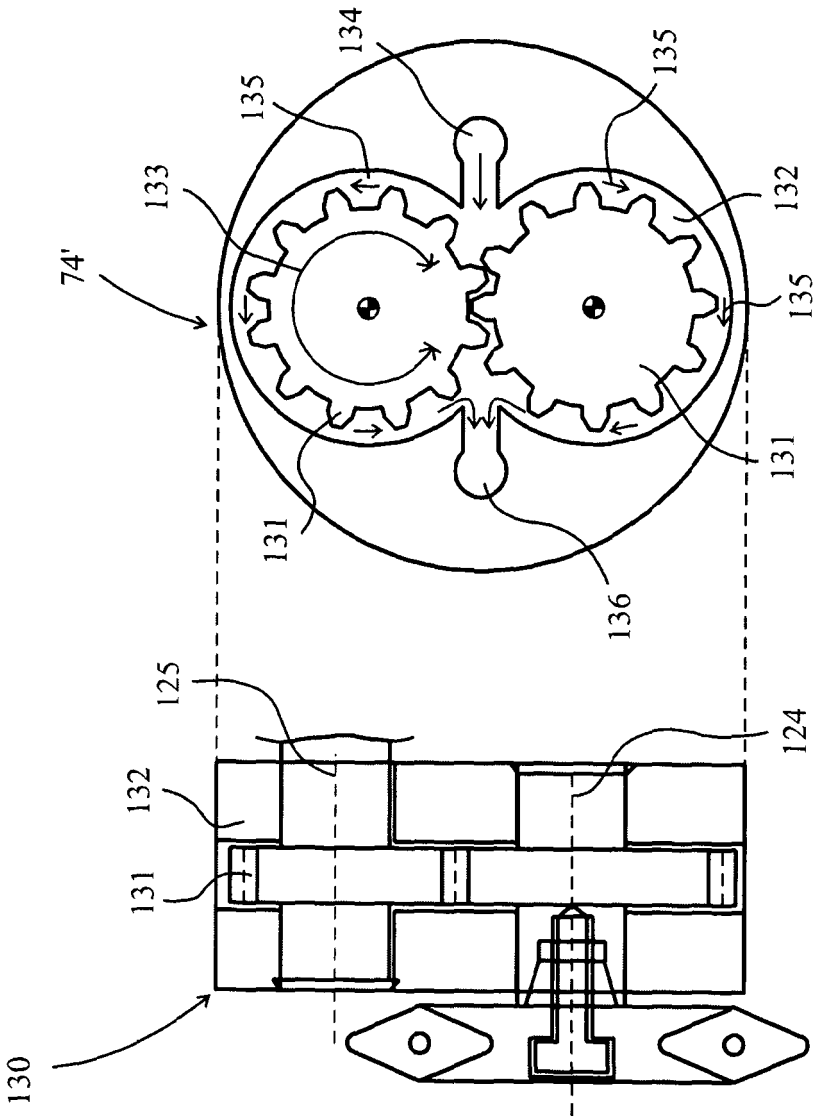


Fig. 13b

Fig. 13a

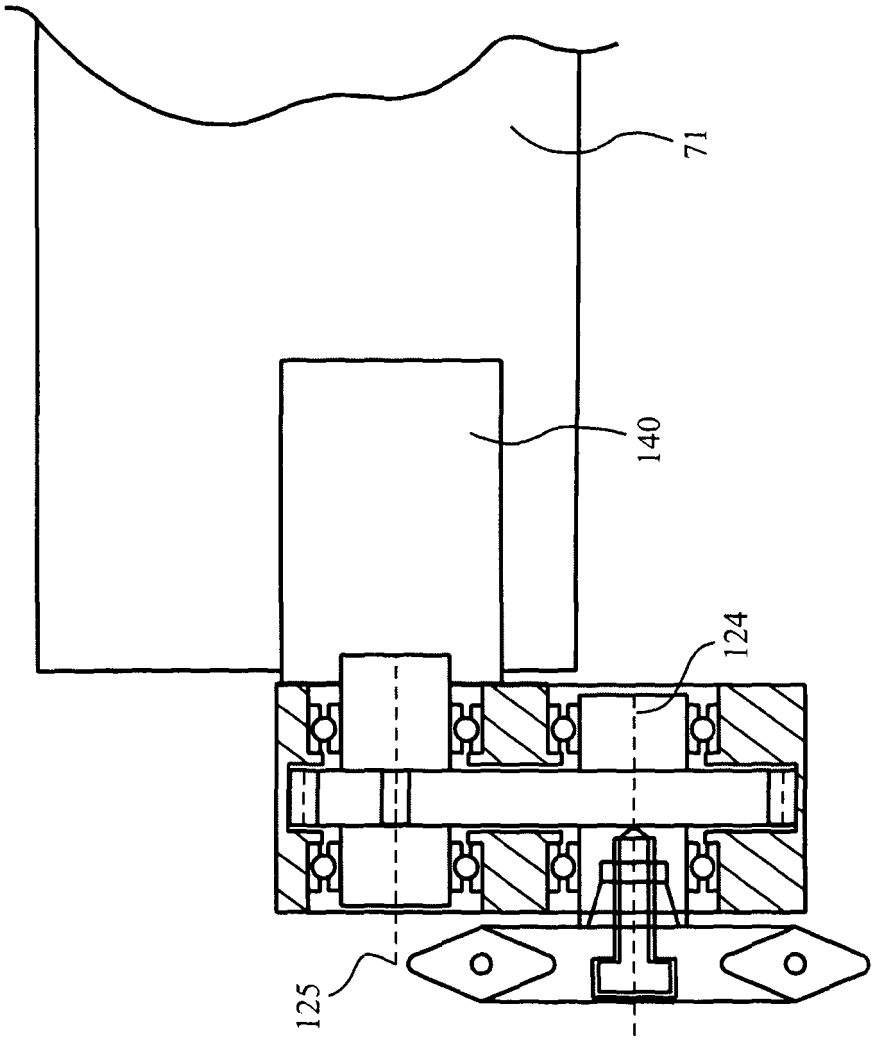


Fig. 14

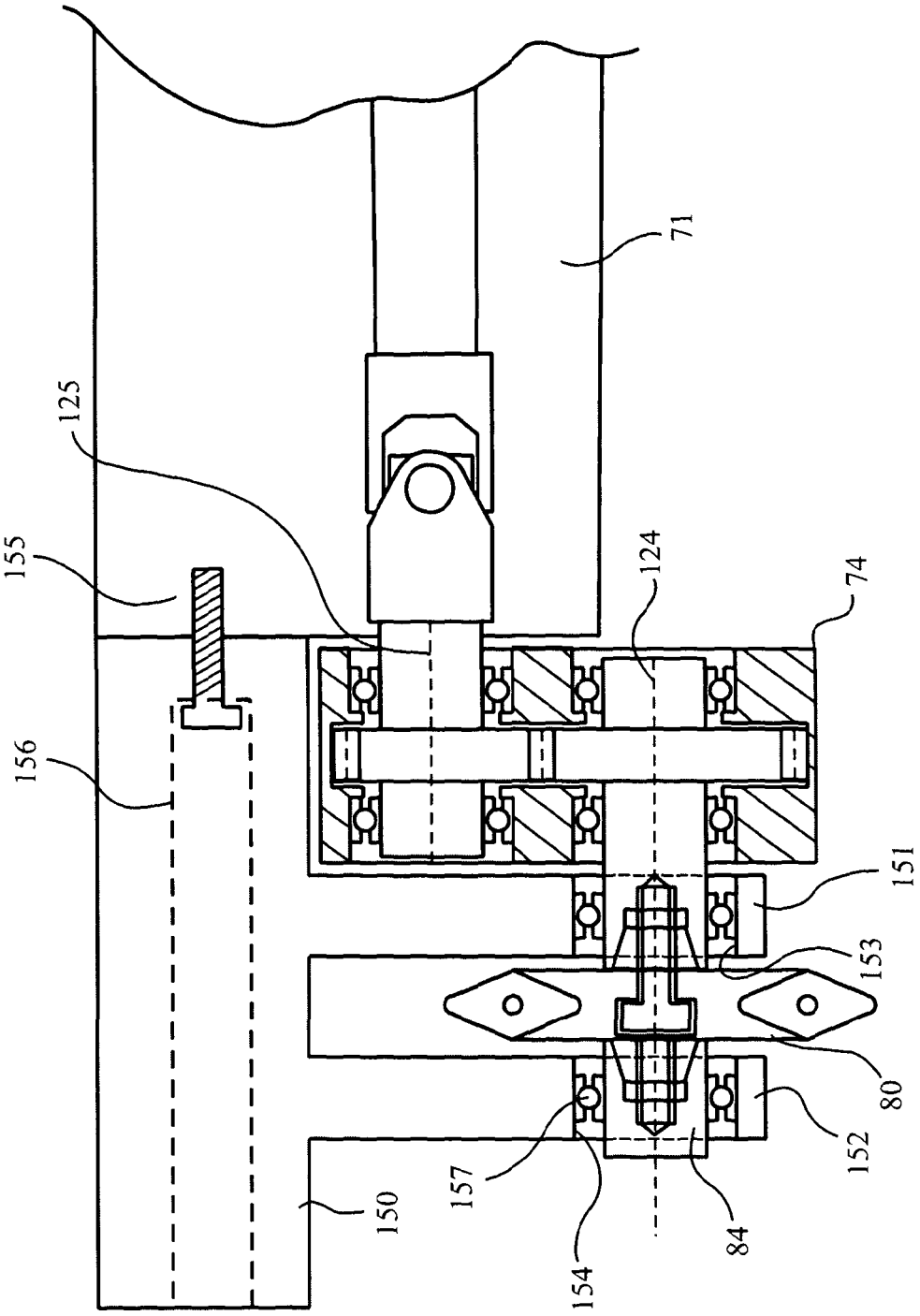


Fig. 15

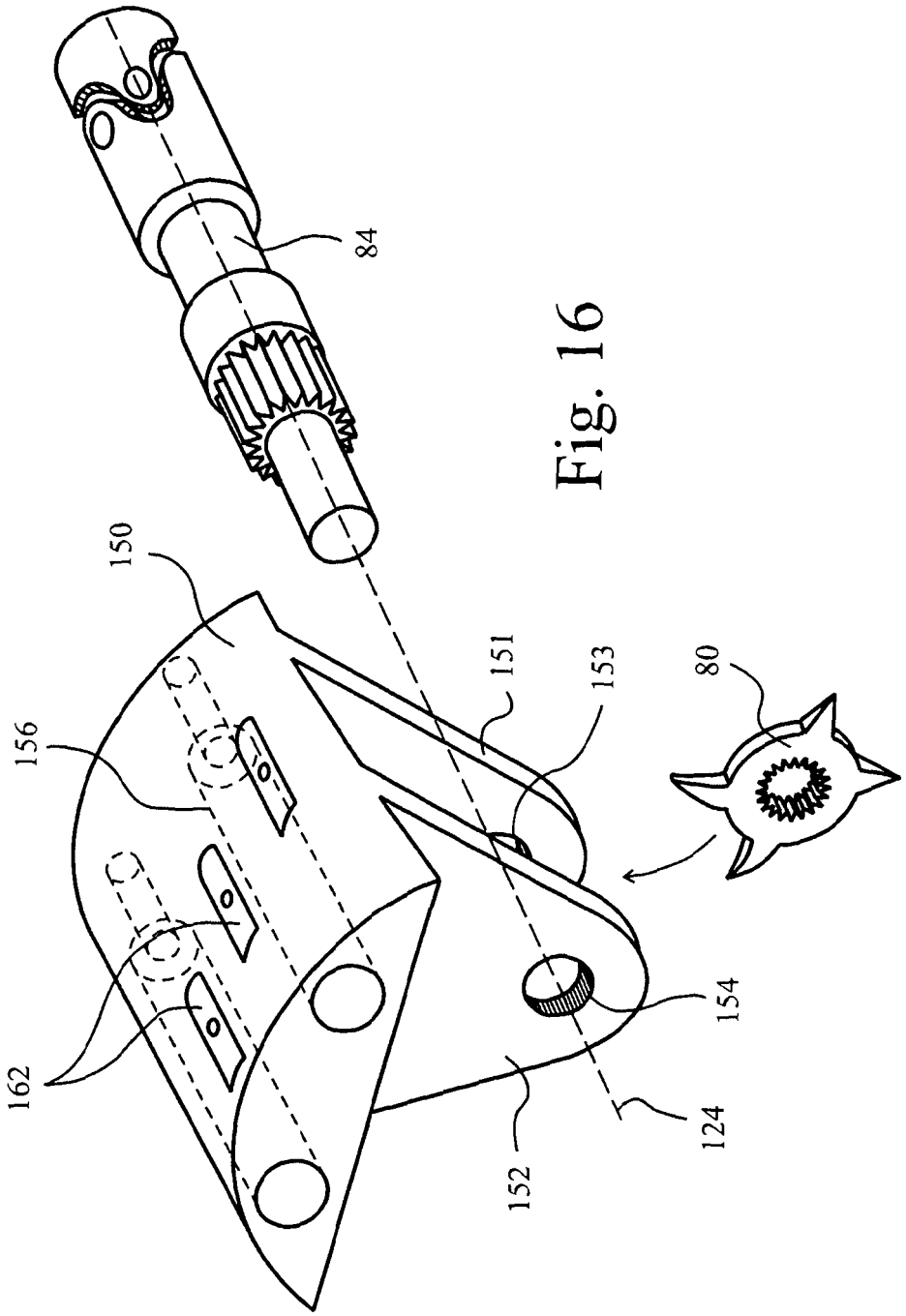


Fig. 16

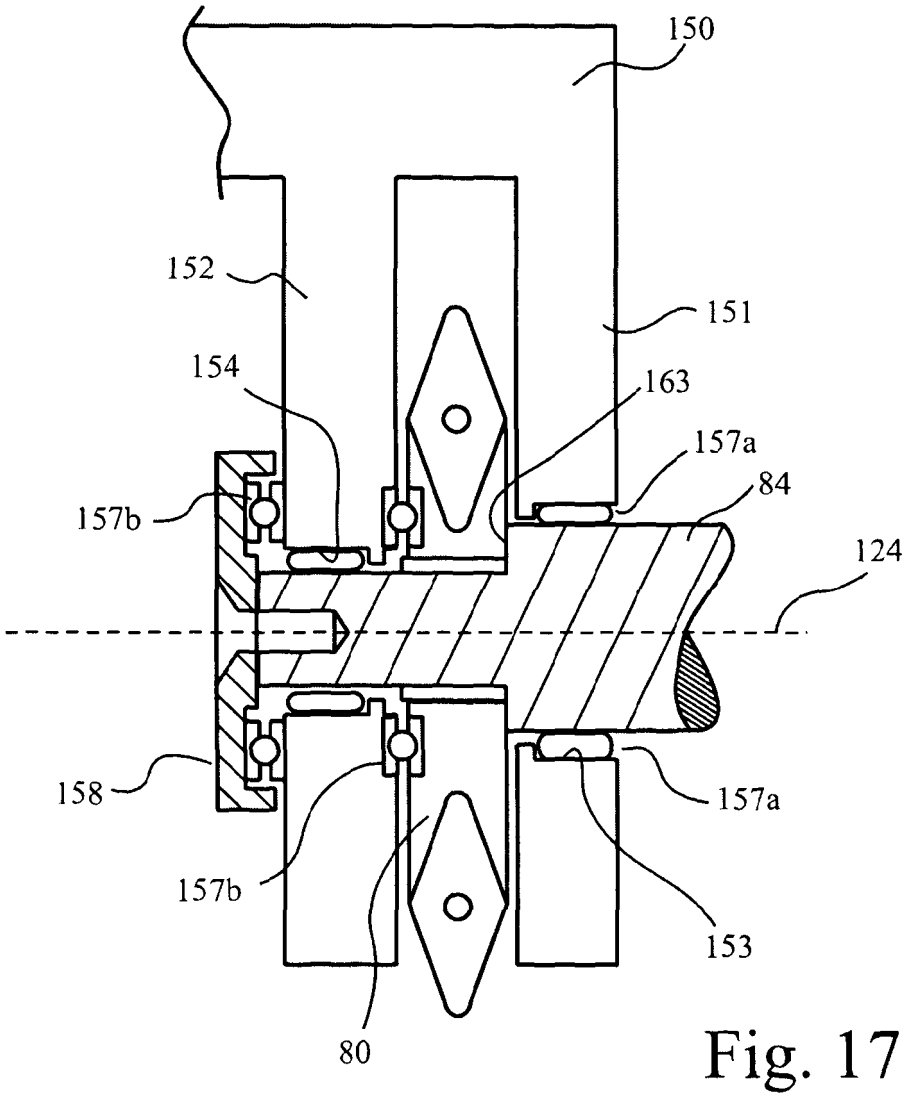


Fig. 17

REFERENCES CITED IN THE DESCRIPTION

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